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THE EFFECTS OF SELECTED TRAINING PROGRAMS
ON A CYCLE AND A TREADMILL ERGOMETER TEST

by



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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Effects of Selected Training Programs on a Cycle and a Treadmill Ergometer Test", submitted by Donald Gordon Watts in partial fulfillment of the requirements for the Degree of Master of Arts.

ABSTRACT

The purpose of the study was to determine the effects of selected training programs on the Sjöstrand PWC₁₇₀ Test and the Johnson, Brouha and Darling Fitness Index.

Eighteen male freshmen and twenty-three varsity athletes from the judo (N=5), hockey (N=9) and swim (N=9) teams were tested before and after their training programs. The freshmen subjects were randomly assigned to two equal groups to train on a bicycle ergometer or a treadmill ergometer at a submaximal workload for five weeks. The athletes underwent a regular season of training. The freshmen subjects were retested for a retention effect after five weeks of detraining.

An additional group of eighteen freshmen volunteers acted as reliability subjects for the Sjöstrand PWC₁₇₀ test and the Johnson, Brouha and Darling treadmill test.

Some additional variables analyzed in the study were the resting heart rate, a submaximal walk heart rate, the maximal heart rate, the sum of the three thirty-second recovery heart rates and the duration of the all-out treadmill run in seconds.

The results showed that after training only the bicycle trained group had a significant increase in the mean PWC₁₇₀ score. However, the bicycle trained group, the hockey team and the swim team revealed significant increases in the mean fitness index after training. When the PWC₁₇₀ and the fitness index were expressed per kilogram of body weight the analysis of variance revealed the same results as when the PWC₁₇₀ and the fitness

index scores were not expressed per kilogram of body weight.

The results indicated no specificity of training among the groups on the Sjöstrand PWC₁₇₀ and the fitness index. There was a decrease of the mean resting heart rate, the mean walk heart rate, the mean maximal heart rate and the mean recovery heart rate of the athletes and non-athletes after training except for the swim team that exhibited an increase of the mean maximal heart rate.

The test-retest reliability coefficients for the PWC₁₇₀ test and the fitness index were .89 and .92 respectively.

The study also revealed that the four best pre-training predictors, excluding the fitness index, of the post-training PWC₁₇₀ were a combination of the treadmill resting heart rate, the maximal heart rate, the sum of the three thirty-second recovery heart rates and the duration of the all-out treadmill run. The standard weights for each of these variables were -.5, -.41, +.34 and +.34 respectively.

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CHAPTER I

STATEMENT OF THE PROBLEM

I. INTRODUCTION

Generally physical training increases the efficiency of performance of any kind of muscular activity provided the workload is submaximal. An individual trained for a specific heavy exercise is more efficient and capable of doing more work of that particular nature than when he performs any other kind of heavy exercise (19).

The specificity of training can be studied when the training effects of regularly performed sports are compared. Studies on groups of male athletes before and during an athletic training season have shown that the nature of training is a specific factor in determining the maximum efficiency that can be attained (17).

The various parameters examined in these studies were: cardiac output, blood lactate level, blood pressure changes, heart rate changes and oxygen consumption. These parameters require expensive equipment and lengthy test periods and are therefore restricted to laboratory situations. Due to the need for practical, simple but valid measures the pulse rate method of determining work capacity has been studied by several researchers (22, 26, 30).

Training studies on athletes and sedentary subjects have shown there is a decrease in the resting pulse rate after a period of physical training (19, 21, 72). Some studies have also indicated a decrease in

the maximal pulse rate at a specific workload after training (7, 42, 72). However, there is a lack of agreement about the importance of the recovery heart rate as an indicator of fitness. Some investigators found that the recovery heart rate is a good indicator of fitness (24, 45, 48, 51, 56, 60). Other investigators have found recovery heart rate to be a poor indicator of fitness or work capacity (31, 68).

After training, the heart rate is lower for a given individual at a specified workload (44) and at a given workload the pulse rate for trained subjects is generally less than the heart rate for the untrained (72).

The most commonly used techniques for determining and adjusting workloads in a laboratory situation are the bicycle ergometer and motor driven treadmill. The tests on both these apparatus are simple and simulate training situations.

A frequently used test with the bicycle ergometer is the Sjöstrand PWC₁₇₀ test. This test has been used to evaluate training programs. Astrand (3) showed that continuous short-term training with varied workloads up to exhaustion was found to induce a gradual increase in the PWC₁₇₀, blood volume and total hemoglobin when compared to physical exercise of a long daily duration but moderate intensity.

Johnson, Brouha and Darling (47) developed a "fitness index" based on the length of a strenuous exercise and the ability of the body to recover from this exertion. The index is of value in detecting physical deterioration in the same man examined at intervals. When a person stops training changes in his index follow closely variations in fitness as determined by other means (47).

The treadmill and bicycle ergometer can be used as training

apparatus. There has been limited research into the effect of how specific training programs affect an individual's performance on these particular pieces of apparatus when used to test work capacity.

The treadmill and bicycle ergometer are designed to test an individual's work capacity under laboratory conditions even though they are orientated to running and bicycling-type exercises. There is a need to know if these tests are specifically designed to evaluate running or bicycling and if the two tests yield similar work capacity scores after a group has undergone a selected training program. There is also a need to know if tests of this type are sensitive to changes in work capacity.

II. THE PROBLEM

The purpose of this study is to determine the effect of five selected training programs on work capacity as measured by the Sjöstrand PWC₁₇₀ test and the Johnson, Brouha and Darling treadmill test.

III. SUB-PROBLEMS

The following sub-problems will be studied:

- (1) The specificity of the Sjöstrand Physical Work Capacity test and the Johnson, Brouha, and Darling Treadmill run.
- (2) The effect of a training program on the resting heart rate, walk heart rate, maximal heart rate and recovery heart rate of athletes and non-athletes.
- (3) The test-retest reliability of the Sjöstrand PWC₁₇₀ test and the Johnson, Brouha and Darling treadmill test.

- (4) The effect of a detraining program on work capacity, resting heart rate, walk heart rate, maximal heart rate, recovery heart rate and fitness index of non-athletes.
- (5) The suitability of the fitness index to act as a predictor of the post-training PWC_{170} .

IV. DELIMITATIONS

- (1) The study is limited to thirty-six male freshmen subjects enrolled in the first year compulsory Physical Education program and twenty-three varsity athletes from hockey, judo and swimming.
- (2) The PWC_{170} score and the Johnson, Brouha and Darlings' fitness index were studied. They, in turn, are dependent upon heart rate response to selected workloads.
- (3) The training program for the experimental groups was only five weeks in duration.
- (4) A statistical control by means of an analysis of covariance was applied to the experimental and athletic groups.

V. LIMITATIONS

- (1) No control was put on the experimental subjects choice of activity during the physical education program. The experimental subjects were asked not to engage in a second training program.

- (2) Temperature and humidity were not controlled.
- (3) All subjects were not tested at the same time on each occasion nor were they tested by the same tester on each occasion.
- (4) No control was put on the type of meal, time of eating or the amount of sleep on the day of testing.

VI. DEFINITIONS

Work Capacity. Work capacity (PWC_{170}) was defined as the working intensity in KPM per minute which the subject could perform at a pulse rate of 170 beats per minute (41).

Workload. The calibrated frictional force applied to a friction belt which the subject had to overcome to continue cycling at a rate of sixty cycles per minute. Workload was the produce of resistance and rate.

Kilopond Meter. The forces acting on one kilogram mass at the normal acceleration of gravity.

Fitness Index. The numerical result obtained by taking the duration of a standard exhausting exercise in seconds multiplied by 100 and divided by twice the sum of the thirty second recovery pulses from one to one and one-half, two to two and one-half and four to four and one-half minutes of a recovery period.

CHAPTER II

REVIEW OF THE LITERATURE

I. SPECIFICITY OF TRAINING

Brouha (19) tested heart rate reactions and the blood lactic acid level of varsity oarsmen and varsity cross-country runners during and after a treadmill test and a rowing test. The treadmill test consisted of running at 7.0 miles per hour on an 8.6 per cent grade for five minutes. The rowing test was performed in a rowing tank for five minutes. The subject performed at twenty strokes per minute for the first four minutes and thirty strokes per minute during the fifth minute. Heart rate was recorded throughout and a blood sample was taken five minutes after the end of the exercise. The cardiovascular reactions to both tests were similar for all subjects. However, the blood lactic acid varied markedly according to the kind of test performed. They found that for a practically identical cardiovascular reaction a runner accumulates more lactic acid when he rows than when he runs, and an oarsman reaches a higher lactic acid level when he runs than when he rows. They concluded that the maximum lactic acid saturation is reached more rapidly and subjectively, exhaustion appears sooner when the subject performs an exercise for which he is not specifically trained compared with the type of exercise for which he is trained.

In another study Brouha (17) tested four groups of athletes before and during an athletic training season. The athletes consisted

of thirteen trackmen, eleven lacrosse players, seventeen oarsmen and a control group. They underwent a six week training program and were tested before and after the training on a bicycle ergometer at 900 kgm/min. for five minutes. Heart rate and blood lactate were recorded. He found that physical efficiency as determined either by a bicycle ergometer or by a treadmill test was always highest after training in the men who were involved in strenuous and prolonged activities such as rowing or cross-country running.

Holmgren et al. (44) studied the effect of different types of training on changes in PWC_{170} , total hemoglobin and blood volume and resting pulse rate. The subjects consisted of hospital personnel who were divided into four training groups: gymnastics training, skiing, cross-country running and skiing in mountainous terrain. They found that the effect on both the workload and the blood volume appears to vary with different training methods. The PWC_{170} increased after continuous short-term training but not in the same proportion to each other as after intermittent long term training. They concluded that physical exercise of long daily duration but moderate intensity seems to have less effect on the workload and the blood volume than training of shorter daily duration with varying workloads up to exhaustion.

Very little research has been conducted in the area of the effect of special training programs on the cardiovascular system. However, much research has been completed on specificity of strength training (12, 36, 70) and task specificity of motor learning (5, 9, 54). Further studies could apply some of the principles developed from these two areas to the field of specificity of cardiovascular training.

The limited literature on the topic indicates a specificity of training effect on the results obtained on work capacity tests. An individual who trained by running would then be expected to perform better on a running test than on a rowing or pedalling test. This difference may not appear in heart rate reactions but in lactic acid level.

II. SELECTION OF A TRAINING STIMULUS

Research on strength training has produced debatable information about the selection of a training stimulus (12, 58, 59, 70). A similar situation exists when a training stimulus is required to provide changes in the cardiovascular system.

Astrand (3) does not think it desirable to train at a maximal rate because the maximal oxygen uptake is actually attained at a sub-maximal speed or workload. His impression is that a speed which only loads the oxygen transport system maximally is as effective as any higher speeds, perhaps even more effective since the heart rate may continue to rise without a further increase in oxygen uptake. If this is the case, the stroke volume would probably decrease somewhat at higher speeds. The energy cost of the additional speed is covered by anaerobic processes, resulting in much higher lactic acid levels and increased discomfort. Astrand (3) states that in the non-athlete the development of submaximal workloads for some two or four minutes repeated several times is probably a very effective, preferable and lazy way to train circulation.

Karvonen (49, 50) and DeVries (30) stated that to improve the exercise tolerance of the heart the intensity of the workout must exceed a critical threshold value. This was expressed as attaining a heart

rate of sixty per cent of the range between resting and maximal rate.

Holmann and Venrath (43) demonstrated that a half an hour training session four times a week of a moderate intensity (heart rate 115 - 125 beats per minute in training) lead to a lower heart rate at rest as well as during submaximal exercise, but produced no significant change in maximal oxygen uptake or heart volume. After an additional five weeks of training on a heavy workload (heart rate 170 - 180 beats per minute) the maximal oxygen uptake and the heart volume increased.

Holmgren et al. (44) and Holmann and Venrath (43) observed that physical training of moderate intensity or of high intensity but of very short duration resulted in a decrease of the heart rate during work without measurable changes in the circulatory dimensions. Long periods of training as in athletics probably give morphological changes and the circulatory dimensions are increased resulting in a large aerobic work capacity. This study indicated that in order to produce significant changes in circulation dimensions such as blood volume, stroke volume, hemoglobin level and peripheral circulation, long periods of intensive training must be performed rather than short periods of high intensity or long periods of moderate intensity.

The literature seems to indicate that a training program that produces a heart rate above sixty per cent of the range between the resting and the maximal rate will produce changes in efficiency of the heart rate at rest, during exercise and during recovery period. However, long periods of heavy exercise are required if changes in the aerobic work capacity are desired.

III. EFFECT OF TRAINING ON THE RESTING HEART RATE

Almost without exception in the published reports a relative bradycardia has been mentioned as a characteristic of the trained state.

Knehr, Dill and Neufeld (53) trained a group of men by having them walk for eight minutes at 3.5 m.p.h. on an 8.6 per cent grade and then run on the same grade for five minutes at 7.0 m.p.h. They found there was a decrease in the resting pulse rate of five beats per minute from 66.8 to 61.8 following the training program.

Similar results have been found by other researchers (13, 17, 19, 34, 55).

Brouha and Heath (21) stated that it is customary to assume that the resting pulse of a normal adult man is about seventy beats per minute. Resting pulses as low as forty beats or even less have been observed in men who were accustomed to long and hard physical performances and who had been under fairly continuous training for a period of years. Brouha (19) also states that it is not exceptional for the resting pulse rate to be reduced by ten to twenty beats per minute between the beginning and the end of the training period.

In a study by Cogswell et al. (22) on seven volunteers aged twenty-three to twenty-eight years who trained for six weeks and were tested on a step test, a treadmill test and an ergometer test there was no decrease in resting pulse rate as training progressed.

In one study Karvonen and Barry (50) found that the circulation of the trained individual at rest is manifested by a low cardiac output, mediated by a slow heart rate and reduced stroke volume. In other studies Karvonen (49) reports reduced heart rates and

increased stroke volumes after training non-athletic subjects. Frick et al. (34) revealed reduced heart rates and increased stroke volumes after training of sedentary subjects. Wang et al. (73) and associates found similar results.

Therefore it can be concluded that after a training program there is a decrease in the resting heart rate. The literature reports only a few instances when there is no significant decrease in the resting heart rate. Many environmental factors can affect the reading: anxiety, time of day, activity before the reading was taken, ingestion of food, temperature and method of recording the heart rate.

IV. EFFECTS OF TRAINING ON MAXIMAL HEART RATE

Andersen and Hermansen (7) stated that the term maximal heart rate may be misleading. It has never been demonstrated that the highest heart rate recorded during exhaustive exercise is maximal in the sense that the heart is unable to produce a higher frequency. The possibility exists that the heart is not maximally activated even during the heaviest workload.

Taylor (68) found that the level of heart rate during exercise has been shown to be proportional to the workload. After a period of training the heart rate accelerates less for a given task. Knehr, Dill and Neufeld (53) found that the increased efficiency of grade walking was accompanied by a decreased heart rate of about four per cent.

Wahlund (72) found that when very heavy work leading to exhaustion is considered, pulse rates of approximately 170 to 200 are found. At high levels of work the linear relation is not always consistent, pulse rate increases being somewhat retarded in relation to workload. Wahlund

(72) concluded that for a given workload the pulse rate of trained subjects was generally less than for others and that during training the pulse rate decreases gradually. This has been supported by other researchers (19, 60).

Hermansen and Andersen (42) studied twenty-six young men, fourteen being cross-country skiers, on the characteristic of maximal heart rate during exercise. He found that the athletically trained subjects averaged lower rates than did the sedentary subjects (178 ± 6.5 for athletes and 189 ± 8.3 for the sedentary). This phenomenon has also been supported by Bock et al. (15) and Wang et al. (73).

Boas (14) studied the effect of exhausting exercise on the heart rate of twenty-seven boys ranging from nine to fifteen years during a run up and down a corridor and then up and down stairs. He concluded that the absolute maximum heart rate attained does not depend on either the initial resting pulse rate nor on the duration of the exercise but on the workload. Boas (14) did not take the heart rate at different times in the exercise nor did he use two groups, thus his findings are debatable.

Therefore it would seem that training can produce a reduction in the maximal heart rate for a given task or workload. The important factor in producing the effect appears to be the length and intensity of the training program.

V. EFFECT OF TRAINING ON THE RECOVERY HEART RATE

Horniak (45) states that after exercise and during recovery, the return of the pulse rate to normal depends mostly on the degree of

fitness.

In a study by Boas (14) on twenty-seven boys he found that in the case of the boys who were in better physical condition the reduction in heart rate after exercise occurred a little more rapidly. The speed with which the heart rate returned to normal was not influenced by a maximum rate that had been reached during the exercise. Cogswell et al. (22) confirmed this latter statement. Cogswell et al. also found that in submaximal exercise, post exercise pulse rates showed a decrease with training, whereas maximal tests failed to produce a similar response.

Andrew et al. (8) studied the effect of a training program on athletes and non-athletes and he found that after training the heart rate fell in all subjects at all loads although the differences were significant in only three comparisons; non-athletes at 350 and 550 kg./min. and athletes at 550 kg./min. Brouha (19), Andersen and Hermansen (7), Montoye (57) and Michael and Gallon (56) found similar results.

Johnson, Brouha and Darling (47, 48) used the recovery heart rate as an index of a persons fitness level. The recovery heart rate measurements were taken after performances on treadmill and step tests.

Cotton and Dill (24) and Schneider (60) have also used pulse rate recover in tests of fitness.

However, not all researchers are in agreement that recovery heart rate is a good indicator of fitness. Durnin et al. (31) and Taylor (68) have shown that exercise heart rate is a better indicator of fitness than recovery heart rate.

There is limited agreement about the effect of training on the

recovery heart rate. Some investigators have found that there is an improvement of the recovery heart rate after a training period and that this recovery heart rate is a good indicator of a persons fitness level. However, other investigators have shown that there is no significant improvement of the recovery heart rate after a training period and therefore the recovery heart rate should not be used as an indicator of fitness.

VI. EFFECT OF DETRAINING UPON HEART RATE AND WORKLOAD

Brouha (19) stated that when training involves a moderate level of activity, it can be interrupted for as long as a week or ten days without any sign of deterioration during a standard exercise test. When exercise is heavy, interrupting training for no more than four to six days is immediately followed by a decrease in efficiency as indicated by faster heart rate and higher concentration of lactic acid in the blood.

Hammer (39) found that if a period of training is followed by one of no systematic training the pulse rate, following a standard bout of exercise (Harvard step-test), will increase again until it approaches the pulse rates registered before systematic training was begun.

Similar results have been found by Michael and Gallon (56) and Mayer (55).

The literature on detraining indicates that the resting heart rate increases and the maximal heart rate increases for a given workload after a period of detraining following a training program. There is also a decrease in the amount of work that can be completed by a subject after a period of detraining.

VIII. DEVELOPMENT OF THE SJÖSTRAND TEST

The bicycle ergometer is an instrument used for both maximal and submaximal tests (1, 2, 10, 64, 71). Sjöstrand (63, 64, 65, 66) has reported a close relationship between exercise intensity and stroke volume at a pulse rate of 170 beats per minute. In the Sjöstrand submaximal test a line is drawn for each subject on the basis of two or three points plotted on a graph of heart rate vs. workload. The best fitting straight line is extrapolated to give a workload value for a heart rate of 170 beats per minute. This is called the subject's physical working capacity at a heart rate of 170 beats per minute.

Sjöstrand (63) studied the physical work capacity of twenty workmen employed in an ore smelting factory. The workloads used were 300, 600, 900 and occasionally 1,200 kpm./min. for a ten minute interval at each work level except the last which was either six or four minutes. This work was continued at a rate of 300 M/min. until the heart rate was either greater than 175 beats per minute or the increase between the first determination and the last was more than 10 beats per minute. When the critical level was reached the next lower load was considered the highest which could be maintained without signs of inefficiency of respiration and circulation.

Wahlund (72) tested 469 adult males on a bicycle ergometer starting at a workload of 300 or 600 kpm/min. and increasing the workload every six and one-half minutes by 300 kpm/min. until the subject could not continue or work at 1,200 kpm/min. Throughout the test the pulse rate was taken at two minute intervals.

Wahlund (72) concluded that it was possible to estimate the

limit of cardiac output by studying the individual's pulse curve. He set the maximum heart rate at which work may be performed adequately at 170 beats per minute. If this heart rate is not reached then the workload which could be done at that heart rate could be calculated on the basis of a linear relationship between workload and heart rate. This is called the Physical Work Capacity₁₇₀ (PWC₁₇₀).

Kjellberg et al. (52) modified the Sjöstrand test by shortening the time pedalled at each workload to six minutes and extrapolation of the pulse curve to 170 if that pulse rate was not achieved.

Bengtsson (11) modified the Sjöstrand test by attempting to adjust workloads so that the heart rate would be approximately 125-130, 140-150 and about 170 beats per minute for each successive workload.

Adams et al. (2) used the Sjöstrand test to study 243 normal white school children in California. They modified the test by attempting to schedule the workloads for each subject so that the first workload produced a heart rate of 100-120 beats per minute, the second produced 120-140 beats per minute and the last 150-170 beats per minute.

Adams et al. (1) further modified the Sjöstrand test when they tested 196 Swedish children of both sexes, ages ten, eleven and twelve years from city and country areas. They used two workloads and tried to obtain heart rates of about 140 beats per minute in the first level and approximately 170 beats per minute in the second.

In Canada extensive use has been made of the Sjöstrand test by Cumming and Cumming (25), Cumming and Young (27), Cumming and Danzinger (26) and the Research Committee of the Canadian Association for Health, Physical Education and Recreation.

IX. DEVELOPMENT OF THE JOHNSON, BROUHA AND DARLING

FITNESS INDEX

Johnson, Brouha and Darling (47) reported the results of investigations about physical fitness testing. They developed a fitness test that utilized simple measurements that gave a wide spread of scores between the fit and the unfit. From experimental results they concluded that work which can be maintained in a steady state by all subjects however unfit, was of little help in assessing fitness for hard work, mainly because the differences between fitness and unfitness are arithmetically smaller the lower the metabolic rate (47). This necessitates using hard work as the standard exercise if fitness for hard work is in question. The index was defined so that the scores are expressed in whole numbers. One hundred is very good and forty is the dividing line between poor and fair. The index was calculated from the following formula:

$$\frac{\text{length of exercise in seconds} \times 100}{2 \times \text{sum of pulses from } 1 - 1\frac{1}{2}, 2 - 2\frac{1}{2} \text{ and } 4 - 4\frac{1}{2} \text{ minutes in recovery}}$$

From studies Brouha (20) developed the following rating scale for the fitness index:

Below 55	. . . . .	poor
55 - 64	. . . . .	low average
65 - 79	. . . . .	average
80 - 89	. . . . .	good
above 90	. . . . .	excellent

Johnson et al. (48) has used the fitness index for different types of exercise: treadmill running, pulling a 'stoneboat', rowing against a heavy load, pedalling on a bicycle ergometer and bench stepping. He stated that the type of exercise is not particularly important but it must

fulfill these conditions:

- (a) The activity must put the cardiovascular system under considerable stress by involving large muscle groups.
- (b) The activity must be of such intensity that about one-third of all subjects stop from exhaustion within five minutes.
- (c) The activity must not demand an unusual skill for its successful performance.

Glassford et al. (38) gave three direct tests and one indirect test of maximal oxygen uptake to twenty-four male subjects aged seventeen to thirty-three. The direct tests were those of Mitchell, Sproule, and Chapman (treadmill), Taylor, Buskirk and Henschel (treadmill), and Astrand (bicycle ergometer). The indirect test was the Astrand Ryhming Nomogram (bicycle ergometer). In addition the Johnson, Brouha and Darling physical fitness test was used. The two treadmill tests and the indirect test yielded significantly higher mean values than did the direct bicycle test. However, no other significant differences in mean values occurred. The Pearson product-moment correlation coefficients were calculated between the Johnson, Brouha and Darling Physical Fitness scores and values from each of the four maximal oxygen uptake tests. The coefficients were found to be significant and ranged from .68 to .83. These correlation coefficients show that the Johnson, Brouha and Darling Treadmill test is a good indicator of the maximum oxygen uptake which is a good indicator of fitness. No correlation obtained proved to be significantly greater than any other. The results also indicated that direct treadmill tests employing greater muscle mass yield higher

maximal oxygen uptake values (eight per cent) than does the direct bicycle test.

X. RELIABILITY OF WORK CAPACITY TESTS.

Cumming and Danzinger (26) do not give any figures but they report that there was no significant difference between working capacity means for nineteen boys and twenty-two girls when retested.

Zahar (75) reported test-retest reliability coefficients of .886, .894, .877 and .947 on six tests of the Sjöstrand bicycle test in Edmonton school children. Each coefficient was significantly greater than zero at the $p = .01$ level of confidence.

Borg (16) found high reliability coefficients of .09 and .97 on the Physical Work Capacity test.

XI. BODY WEIGHT AND WORK CAPACITY

Cumming and Cumming (25) report a correlation between weight and PWC_{170} of .897 and .696 for Winnipeg boys and girls respectively.

Adams et al. (2) found a correlation of .81 for boys and .77 for girls when comparing weight to physical work capacity of California children. But in another study Adams and others (1) found correlations of between .27 and .65 for the same measures on Swedish children.

Taylor (68) found that in submaximal exercise, oxygen consumption was chiefly a function of body weight and only slightly related to fitness, but in maximal work the relationship with weight dropped sharply and the correlation with the fitness criterion increased.

Johnson, Brouha and Darling (47) stated that whatever type of

exercise is used for the fitness index test all subjects must work at a rate linearly proportional to the body weight. Running uphill necessarily causes a subject to work at a rate proportional to his weight. However, Brouha does not give any statistical support to this statement.

XII. BODY HEIGHT AND WORK CAPACITY

For boys a correlation of .83 was found between leg height and work capacity by Adams et al. (2). For these parameters on girls it was .76.

In Sweden Adams et al. (1) were not able to obtain such high correlations on the parameters of height and work capacity. They ranged from .30 to .39.

Cumming and Cumming (25) found a correlation of .856 for boys and .658 for girls for height and work capacity on the Sjöstrand test in a Winnipeg test.

CHAPTER III

METHODS AND PROCEDURE

I. SUBJECTS

The first sample for the study consisted of eighteen voluntary male freshmen enrolled at the University of Alberta. They were randomly designated to one of two experimental groups; a bicycle training group or a treadmill training group. The second sample consisted of twenty-three male varsity athletes from the hockey, judo and swimming teams. A third group of eighteen male freshmen enrolled at the University of Alberta in Physical Education were volunteers from a bowling class. They took part in a reliability study of the bicycle ergometer and the motor driven treadmill. They were randomly divided into two groups; bicycle reliability group.

II. EXPERIMENTAL DESIGN

The training study lasted for thirteen weeks and was comprised of one week preliminary testing, five weeks training, one week testing, a five week detraining program and one week of testing. The subjects were randomly assigned to the two tests in the first week and they performed these tests in the same order in each subsequent testing session. The subjects trained three days a week with as many as possible training during the afternoons on a Monday, Wednesday and Friday.

All the athletes were tested during the first week of their

preseason training and in the first week after the W.C.I.A.A. Championships or the C.I.A.U. Championships of the particular sport.

The subjects in the reliability groups were tested twice on each test to which they were randomly assigned. They were tested twice with one week between tests. The tests took place at the same time of the day in all cases.

III. ANTHROPOMETRIC DATA

The following anthropometric data was collected from each subject; age (years and months), height (inches) and weight (pounds). These were recorded prior to each testing session.

IV. EQUIPMENT

The heart rate was recorded from two chest electrodes fitted at the first intercostal space directly below each nipple and below the pectoralis major muscle. The reference electrode was fitted below the subjects right scapula. The heart rate was recorded on a Sandborn 500 visocardiette recorder. An electrolytic paste was applied to the electrodes to improve conduction.

The bicycle ergometer was of the von Döbeln type, manufactured by the Monark Company Limited of Sweden. Resistance to the pedalling was provided by a friction belt, operated by a sinus balance, applied against a rotatable wheel. A record of revolutions pedalled was obtained by means of an electrical counter that was connected to a microswitch which rolled on an elliptical collar attached to the pedal axis. Both the seat and the handlebars were adjustable to individual requirements.

An electrical metronome which emitted an auditory stimulus was set to 120 beats per minute thus providing the subject with a guide to pedal rhythm. In this way an attempt was made to elicit a rate of sixty revolutions per minute.

The treadmill was a motor driven treadmill with an adjustable speed range and an angle adjustment.

A clinical type weigh scale with a device for measuring height was used to obtain height and weight.

V. TEST PROCEDURE FOR THE DETERMINING OF PWC₁₇₀

Each training subject, varsity athlete and bicycle reliability subject was tested to determine his Physical Work Capacity at 170 beats per minute. If any adjustment was needed for the height of the seat it was done when the subject first sat on the bicycle. The seat was adjusted so that a straight line was formed from the front of the subjects' knee, past the front of the foot to the floor when the pedal on that side of the bicycle was at the bottom of rotation. Each subject rested for five minutes while seated on the bicycle, during which time the chest electrodes and electrode leads were connected. At the end of the rest the resting heart rate was recorded.

A light initial workload was selected so that at the end of six minutes of pedalling the heart rate would fall between 115 and 130 beats per minute. The subject was asked to start pedalling at a rate of sixty revolutions per minute as determined by the sound emitted from an electric metronome. The workload was applied to the desired workload by tightening the frictional belt by use of a handwheel. The revolution counter connected to the pedal axis was switched on as was the stop watch. This

took place in a time period of three seconds. The workload was checked at least once each minute.

The test lasted for eighteen minutes and the heart rate was recorded at the end of each minute. The workload was increased at the end of the sixth minute so that the heart rate taken during the last three seconds of the twelfth minute would be between 130 and 150 beats per minute. At the end of the twelfth minute the workload was again increased so that the heart rate taken during the last three seconds of the eighteenth minute would be between 150 and 170 beats per minute. At the end of the sixth, twelfth, and eighteenth minutes the total revolutions for the previous six minutes were recorded and an average for each six minutes was calculated. The workload for each six minutes and the heart rate at the end of each of the six minutes of pedalling was recorded. The subject was not allowed to stop throughout the test until he was told to do so at the end of eighteen minutes.

VI. TESTING PROCEDURE FOR THE JOHNSON, BROUHA AND

DARLING TREADMILL TEST

Each training subject, varsity athlete and treadmill reliability subject was tested to determine his Fitness Index. Each subject rested for five minutes while sitting on a chair beside the treadmill. During the rest period the chest electrodes and electrode leads were connected. At the end of the rest period the heart rate was recorded. This was designated as the resting pulse.

The subject stepped onto the treadmill and following a signal from the tester the treadmill was started. The subject walked for five

minutes at a speed of 3.5 miles per hour on an 8.6 per cent grade. During the last three seconds of the walk his heart rate was recorded again.

This was designated as the walk pulse. The subject was then seated and heart rates were recorded after thirty seconds, two and one-half minutes and four and one-half minutes of the recovery period. During the last thirty seconds of rest the treadmill speed was increased to 7.0 miles per hour with a constant grade of 8.6 per cent. The subject stepped onto the treadmill at the end of the five minute rest and the run was commenced. The subject was instructed to run until he was exhausted. No motivation was provided. At the subject's indication of exhaustion the exercise was terminated and a heart rate was recorded. This was designated as the maximal pulse. The stop watch was stopped and the length of the run in seconds was recorded. The subject was seated during which time the recovery heart rates were taken from one to one and one-half minutes, two to two and one-half minutes and four to four and one-half minutes of recovery.

This test was a modification of the Johnson, Brouha and Darling test (47) since the subject was allowed to run to exhaustion rather than being restricted to only a five minute run. The fitness score was computed from the following formula:

$$\frac{\text{Length of exercise in seconds} \times 100}{2 \times \text{sum of pulses from } 1-1\frac{1}{2}, 2-2\frac{1}{2} \text{ and } 4-4\frac{1}{2} \text{ minutes in recovery}}$$

VII. TRAINING PROGRAMS

1. Varsity Athletes. Each athlete trained with the members of the particular team to which they belonged. They did not do any extra training for this study.

2. Bicycle Training Group. The subjects trained three times a week for a period of five weeks. Each training period lasted for six minutes with the work schedule for the first week being two minutes work, one minute rest, two minutes work, one minute rest and two minutes work, For the remaining four weeks of the training period the work schedule was three minutes work, one minute rest, and three minutes work. The pedal revolutions were set at fifty revolutions per minute. The workload was selected so that the heart rate at the end of the sixth minute was between 150 and 170 beats per minute. This selection was based on the results of the individual's performance on the Sj^ostrand test and from the results of a pilot study.

The workloads for each individual remained constant for the first two weeks of the program and then a new workload was applied for the third and fourth weeks. A new workload was applied during the fifth week for those individuals whose training heart rate at the end of the fourth week was less than 150 beats per minute.

The heart rates were recorded after a five minute rest before starting the training, at the end of the three minutes of exercise (at the end of work of the two minute work periods in the first week) and at the end of the sixth minute of exercise.

3. Treadmill Training Group. The subjects trained three times a week for a period of five weeks. Each training period lasted for six minutes with the work schedule for the first week being two minutes work, one minute rest, two minutes work, one minute rest and two minutes of work. For the remaining four weeks of the training period the work schedule was three minutes work, one minute rest and three minutes work. The speed of the treadmill

was constant throughout the training period at six miles per hour. The workload was changed by increasing the grade. The grade during the first two weeks was 3.6 per cent so that the heart rate was between 150 and 170 beats per minute. This was selected on the findings of a study by King (51). The grade was increased at the start of the third week to 5.6 per cent. This remained constant during the third and fourth weeks of training. The grade was increased to 6.1 per cent at the start of the fifth week only for those individuals whose heart rates were below 150 beats per minute, otherwise the grade remained at 5.6 per cent during the fifth week.

VIII. CONDITIONS OF TESTING AND TRAINING

1. Location. The testing of the athletes and the reliability groups took place in the Physical Education Laboratory in the Physical Education Building. The training program and the testing of the training groups took place in the Physical Fitness Laboratory. The Physical Fitness Laboratory was employed because of a lack of space in the Physical Education Laboratory at the time.

2. Temperature, Humidity, and Barometric Pressure. The temperature, humidity and barometric pressure were not controlled, however, the temperature and pressure were recorded.

IX. CALIBRATION OF THE BICYCLE ERGOMETER

The Sinus balance was calibrated by means of a set of standard weights as follows:

- a) The brake drum was removed and the pendulum weight was set

to zero.

- b) A one-half kilogram weight was attached to the spring. The scale mark was adjusted by putting a narrow black mark on the scale to indicate the position for the pendulum mark to fall. If the pendulum mark was accurate to the scale mark already provided on the scale then no additional marks were added.
- c) This process was repeated at the "1 - Kp" and at each quarter scale marking up to and including the "7 - Kp" mark.

X. STATISTICAL TREATMENT

The groups were arranged so two problems could be studied.

The two experimental groups, the bicycle-trained group and the treadmill-trained group, were analyzed to find the effects of five weeks of training and five weeks of detraining on the PWC_{170} scores and the fitness index. An analysis of variance for equal groups (33, 37) was used to analyze the data collected for the two experimental groups. If a significant difference was found between trials or between groups then a Scheffe test (74) was utilized to determine which means significantly differed from each other.

An analysis of covariance (74) was applied to selected post-training and retention variables. The dependent variable or criterion variable was the retention PWC_{170} scores and the covariates were the following post-training variables: PWC_{170} score, fitness index, pre- PWC_{170} test resting heart rate, pre-treadmill test resting heart rate, maximal heart rate, the sum of the three thirty-second recovery heart

rate and the duration of an all-out run, in seconds, on the treadmill.

The two experimental groups and the three athletic teams were analyzed to find the effects of training on the PWC₁₇₀ and Johnson, Brouha and Darling fitness index (47). An analysis of variance for unequal groups was used to analyze the experimental data. If a significant difference was found between groups or between trials then the Scheffe test was employed to determine between what means the significant difference had occurred.

An analysis of covariance (74) was applied to selected variables. The dependent variable was the post-training PWC₁₇₀ scores and the covariates were the following pre-training variables: fitness index, pre-PWC₁₇₀ resting heart rate, pre-treadmill test resting heart rate, maximal heart rate, the sum of three thirty-second recovery heart rates and the duration of an all-out run, in seconds, on the treadmill.

A step-wise regression analysis was employed to determine the best predictor of the post-training PWC₁₇₀ scores. The predictor variables were the same pre-training variables used in the analysis of covariance of the two experimental groups and the three athletic teams.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of the study was to determine the effects of selected training programs on the Sj strand PWC₁₇₀ test and the Johnson, Brouha and Darling fitness index test. The sub-problems studied were the specificity of the PWC₁₇₀ test and the fitness index, the effect of training and detraining programs on selected cardiovascular parameters and the test-retest reliability of the PWC₁₇₀ test and the fitness index (an all-out treadmill run test).

In this chapter the results are presented in the following order: anthropometric conditions of the subjects, the analysis of selected cardiovascular conditions prior to training, the analysis of the selected cardiovascular condition after training, the effects of training on the Sj strand Physical Work Capacity PWC₁₇₀ test, the effects of training on the Johnson, Brouha and Darling Fitness Index, a comparison and discussion of the changes of the PWC₁₇₀ and the Fitness Index with training, the correlation of the PWC₁₇₀ and the Fitness Index and the step-wise regression analysis. In each section the results are presented and then followed by a discussion of the results.

The subjects consisted of eighteen male freshmen students and twenty-three varsity athletes. The freshmen were randomly assigned to two equal experimental groups one of which trained on a bicycle ergometer (E1) and the other on a treadmill ergometer (E2)

at a submaximal workload for five weeks. The athletes consisted of team members from the judo (A1), hockey (A2) and the swim (A3) teams. These groups underwent a regular season of training. All subjects were tested prior to and at the end of their training session on the PWC₁₇₀ test and the fitness index or treadmill test. The E1 and E2 groups were retested for retention after a five week detraining period.

The subjects used for establishing reliability were a separate group of male volunteers from a freshman bowling class. They were randomly assigned to one of two groups, the treadmill reliability group or the bicycle reliability group. Prior to the analysis of the criterion variables the selected anthropometric conditions of the subjects were subjected to an analysis of variance to determine the similarity between the groups before the training program.

I. ANTHROPOMETRIC CONDITIONS OF THE GROUPS

In Table I are shown the means and standard deviations of age, height and weight for all the subjects.

TABLE I
MEAN AND STANDARD DEVIATIONS OF AGE, HEIGHT AND WEIGHT
FOR ALL THE TRAINING GROUPS

Group	Period	AGE		HEIGHT (in.)		WEIGHT (kg.)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
E1	Pre	19.8	1.9	69.9	2.6	68.8	7.6
	Post					69.1	7.7
	Ret.					69.1	8.1
E2	Pre	18.7	.5	70.7	1.7	72.4	7.6
	Post					72.2	7.7
	Ret.					72.7	7.8
A1	Pre	22.6	2.2	69.2	1.6	72.9	9.7
	Post					72.4	8.1
A2	Pre	20.8	1.8	68.7	1.9	72.2	7.0
	Post					75.8	6.6
A3	Pre	20.9	1.9	70.9	2.0	72.8	7.3
	Post					72.2	8.4
Rel.	Test 1	20.2	2.2	69.6	2.2	69.8	9.5
	Test 2					69.8	9.5

There was a similarity among the training groups for age and height prior to and after training as reported in Table I. As can be seen from Table I the mean weights of the groups differ prior to and after training. In order to determine if this difference among groups and between tests was significant an analysis of variance (Table II) was applied to the weights of the training subjects. The calculated F was not significant either among groups or between tests.

TABLE II

ANALYSIS OF VARIANCE OF THE WEIGHTS FOR ALL THE TRAINING
SUBJECTS RECORDED PRIOR TO AND AFTER TRAINING

Source of Variation	SS	df	MS	F
Between Tests	.34	1	.34	.01
Among Groups	401.96	4	100.49	1.73
Interaction	7.42	4	1.85	.03
Error	4181.08	72	58.07	
Total	4590.80	81		

II. ANALYSIS OF SELECTED CARDIOVASCULAR CONDITIONS OF THE TRAINING SUBJECTS RECORDED PRIOR TO TRAINING

The selected physical conditions variables of the subjects that were tested to determine the similarity among the groups prior to training were the resting heart rate recorded before the PWC₁₇₀ test (bicycle resting heart rate), the resting heart rate recorded before the treadmill test (treadmill resting heart rate), and the walk heart rate, the maximal heart rate, the sum of the three thirty-second recovery heart rates and the duration, in seconds, of the all-out run on the treadmill. The means and standard deviations of the bicycle and treadmill resting heart rates for the five groups are recorded in Table III. The percentage differences between the pre-training and post-training and between the post-training and retention means are also shown in Table III.

TABLE III
MEANS, STANDARD DEVIATIONS AND PERCENTAGE DIFFERENCES
OF THE TWO RECORDED RESTING HEART RATES FOR
THE TRAINING GROUPS

Group	Period	Bicycle Resting Heart Rate			Treadmill Resting Heart Rate		
		Mean	S.D.	% Diff.	Mean	S.D.	% Diff.
E1	Pre	91.3	20.9		85.8	16.9	
	Post	78.7	8.5	-13.9	71.8	14.0	-5.9
	Ret.	78.8	11.3	+ 0.0	81.2	12.7	+5.4
E2	Pre	81.2	11.7		79.1	10.9	
	Post	76.4	10.8	-16.3	68.7	7.2	-13.1
	Ret.	72.3	14.4	+13.4	70.8	9.2	+ 3.1
A1	Pre	81.6	18.3		83.4	9.5	
	Post	72.6	11.2	-11.0	74.4	9.3	-10.8
A2	Pre	66.9	6.7		74.0	13.1	
	Post	65.3	12.9	- .8	66.7	12.6	- 6.3
A3	Pre	67.1	12.8		60.2	14.2	
	Post	67.3	14.4	+0.0	65.1	14.3	+ 8.1

Prior to training there was a difference among the groups (Table III) on the bicycle resting heart rate. An analysis of variance was used (Table IV) to determine if this difference among the groups was significant. The calculated F ratio was significant and further analysis by the Scheffe test revealed that the experimental groups E1 and E2 had significantly higher bicycle resting heart rates than the hockey team and the swim team respectively. However there was no significant difference between either of the experimental groups nor were there significant differences among the athletic teams.

TABLE IV
ANALYSIS OF VARIANCE OF THE PRE-TRAINING BICYCLE
RESTING HEART RATE FOR THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Among Groups	3912.88	4	978.22	4.64**
Within	7596.69	36	211.01	
Total	11509.57	40		

**p = .01

As can be seen from Table III the mean treadmill resting heart rate for the training groups were not similar prior to training. In order to determine if the groups differed significantly from each other an analysis of variance (Table V) was performed. The F ratio for the among groups effect was significant. The Scheffe test revealed that the mean treadmill resting heart rate for the swim team was significantly lower than that of the judo team (A1) and groups E1 and E2. Groups E1 and E2 had similar resting heart rates.

TABLE V

ANALYSIS OF VARIANCE OF THE PRE-TRAINING TREADMILL

RESTING HEART RATE FOR THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Among Groups	3496.5	4	874.1	4.79**
Within	6569.31	36	182.48	
Total	10065.81	40		

**p = .01

In Table VI are shown the means and standard deviations of the walk heart rate and the maximal heart rate for the five groups. Also shown are the percentage changes between the pre-training and the post-training recordings and between the post-training and the retention recordings of the walk heart rate and the maximal heart rate.

TABLE VI

MEANS, STANDARD DEVIATIONS AND PERCENTAGE DIFFERENCES OF THE

WALK HEART RATE AND THE MAXIMAL HEART RATE

FOR THE TRAINING GROUPS

Group	Period	Walk Heart Rate			Maximal Heart Rate		
		Mean	S.D.	% Diff.	Mean	S.D.	% Diff.
E1	Pre	147.3	22.3		179.4	18.2	
	Post	132.7	17.5	-9.91	185.1	9.2	+3.2
	Ret.	137.7	19.9	+3.8	184.6	12.4	-0.3
E2	Pre	153.8	14.4		185.8	8.1	
	Post	126.4	10.7	-17.8	186.0	8.1	+0.1
	Ret.	132.6	12.6	+4.9	187.2	9.4	+0.6
A1	Pre	136.8	12.0		189.4	4.8	
	Post	133.4	23.5	-2.5	185.8	4.1	-1.9
A2	Pre	137.4	6.4		179.2	17.1	
	Post	124.0	11.3	-9.8	182.8	5.6	+2.0
A3	Pre	124.4	8.0		168.4	12.8	
	Post	116.6	11.7	-6.3	178.8	12.9	+6.2

The mean walk heart rates for the training groups prior to training are not similar as indicated in Table VI. An analysis of variance (Table VII) was applied to the pre-training walk heart rates for the groups to determine if similarity existed among the groups. The analysis yielded a significant difference among the groups. The Scheffe test indicated that the significant differences among the scores occurred between the two experimental groups and the swim team. It was concluded that the athletes and the non-athletes were not similar on the walking heart rate recorded prior to training.

TABLE VII
ANALYSIS OF VARIANCE OF THE PRE-TRAINING WALK HEART
RATE FOR THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Among Groups	4345.03	4	1086.26	20.25**
Within	2145.02	36	53.63	
Total	6490.05	40		

**p = .01

As can be seen in Table VI the mean maximal heart rates for the training groups prior to training were not similar. An analysis of variance of the pre-training maximal heart rates (Table VIII) was employed to determine if the differences among the scores for the groups were significant. The F ratio yielded a significant difference among the groups and further analysis revealed that the high mean maximal heart rates for the judo team and the E2 group were significantly higher than the mean maximal heart rate for the swim team. There was a significant difference of the maximal heart rate response between the subjects in the experimental groups and the subjects in the athletic groups. There was no significant difference in the mean maximal heart rate for the two experimental groups. Among the athletic teams the judo team did not have a mean maximal heart rate similar to that of the swim team.

TABLE VIII

ANALYSIS OF VARIANCE OF THE PRE-TRAINING MAXIMAL HEART
RATE FOR THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Among Groups	1945.0	4	486.25	2.53*
Within	6922.0	36		
Total	8867.0	40		

*p = .05

The means and standard deviations of the sum of the three thirty-second recovery heart rates and the duration, in seconds, of the all-out treadmill run are recorded in Table IX. Also shown are the percentage differences between the pre-training and the post-training and the retention tests.

TABLE IX

MEANS, STANDARD DEVIATIONS AND PERCENTAGE DIFFERENCES OF THE
SUM OF THE THREE RECOVERY HEART RATES AND THE DURATION OF
THE ALL-OUT RUN FOR THE TRAINING GROUPS

Group	Period	Sum of the Three Recovery Heart Rates			Duration of the All-Out Run		
		Mean	% Diff.	S.D.	Mean	% Diff.	S.D.
E1	Pre	191.3		22.9	152.3		40.3
	Post	187.0	-2.2	17.1	232.0	+52.3	81.7
	Ret.	189.8	+1.5	19.6	187.1	-19.4	50.6
E2	Pre	192.2		11.8	151.0		18.7
	Post	187.8	-2.3	8.7	218.8	+44.9	41.9
	Ret.	184.9	-1.5	14.2	185.4	-15.3	40.2
A1	Pre	189.2		14.1	269.4		97.7
	Post	171.4	-9.4	18.0	209.4	-22.3	69.8
A2	Pre	182.8		10.6	232.9		72.4
	Post	173.4	-5.1	9.1	321.0	+37.8	104.2
A3	Pre	166.2		17.5	237.4		127.7
	Post	163.2	-1.8	20.6	372.4	+56.9	214.3

The sums of the three pre-training recovery heart rates for the training groups (Table IX) are not similar. An analysis of variance (Table X) was performed on the data to determine if the group scores were significantly different from each other. The calculated F ratio was significant and a Scheffe test was performed to determine what groups deviated from each other. It was revealed that the E1 and E2 groups had mean recovery heart rates significantly higher than the mean recovery heart rate for the swim team. There were no differences among the athletic groups or between the two experimental groups.

TABLE X

ANALYSIS OF VARIANCE OF THE SUM OF THE THREE RECOVERY
HEART RATES FOR THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Among Groups	4096.0	4	1024.0	3.89**
Within	9467.0	36	262.97	
Total	13563.0	40		

**p = .01

As can be seen in Table IX there was a difference in the length of time run on the treadmill for the training groups. An analysis of variance was performed to determine if these differences were significant. The calculated F showed a significant difference among the groups. The Scheffe test revealed that the judo team ran significantly longer than groups E1 and E2. The times run by the two experimental groups were similar as were the times run by the three athletic groups. The athletes performed significantly better than did the experimental subjects.

It was concluded that the two experimental groups were similar for the selected cardiovascular conditions recorded prior to training. The athletes were also similar for the same selected cardiovascular conditions. However, the experimental groups differed from the athletes on the bicycle resting heart rate, the treadmill resting heart rate, the walk heart rate, the maximal heart rate, the sum of the three thirty-second recovery heart rates and the duration of the all-out run recorded

prior to training. The athletes in this study were more active prior to training than the two experimental groups and this would account for the statistical differences that existed between the athletes and the experimental subjects.

TABLE XI

ANALYSIS OF VARIANCE FOR THE PRE-TRAINING DURATION OF
THE ALL-OUT TREADMILL RUN FOR THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Among Groups	88,129.0	4	22,032.3	3.3*
Within	240,575.0	36	6,682.6	
Total	328,704.0	40		

*p = .05

III. THE EFFECT OF TRAINING ON SELECTED

CARDIOVASCULAR PARAMETERS

The same cardiovascular conditions that were tested for similarity between the groups prior to training were analyzed after training and detraining to study the changes within the groups and between the groups. The means and standard deviations for the bicycle resting heart rate, the treadmill resting heart rate, the walk heart rate, the maximal heart rate, the sum of the three thirty-second recovery heart rates and the duration of the all-out run are reported in Table III, VI and IX respectively.

Changes in the Resting Heart Rate

The mean bicycle resting heart rates (Table III) for the two

experimental groups indicate that there were very small differences between the two groups on the post-training and retention tests and among the scores on the pre-training, post-training and retention tests. In order to determine if there were significant differences between the groups and among the tests an analysis of variance was applied to the data. The analysis of variance (Table XII) yielded no significant difference either between the two groups or among the tests.

TABLE XII

ANALYSIS OF VARIANCE OF THE BICYCLE RESTING HEART

RATE FOR THE EXPERIMENTAL GROUPS

Source of Variation	SS	df	MS	F
Among Tests	1170.26	2	585.13	3.2
Between Groups	528.91	1	528.91	2.89
Interaction	140.26	2	70.13	.38
Error	8767.76	48	182.65	
Total	10606.76	53		

When the mean bicycle resting heart rates for all the training groups (Table III) are examined there are large differences between the group means on the post-training test and there are decreases in the mean scores for the groups after training. The calculated F (Table XIII) for the among groups effect was significant. Further analysis by the Scheffe test revealed that there was a significant difference among the

groups on the pre-training test but there was no significant difference among the groups on the post-training test.

TABLE XIII

ANALYSIS OF VARIANCE OF THE BICYCLE RESTING HEART
RATE FOR ALL THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	568.98	1	568.98	3.24
Among Groups	4567.45	4	1141.86	6.51**
Interaction	494.91	4	123.73	.7
Error	12636.18	72	175.50	
Total	18297.52	81		

**p = .01

There was also no significant difference revealed between the pre-training and post-training mean bicycle resting heart rates for any of the training groups.

An examination of the mean bicycle resting heart rates in Table III indicate that the effect of training on the experimental group was intensive enough to produce a decrease in their mean resting heart rate. After training the mean scores of the teams were not significantly different as outlined in the previous discussion of Table XIII.

The percentage decrease for the judo team, the hockey team and the swim team were non-significant as compared to the percentage decrease for groups E1 and E2 after training. It is interesting to note (from Table III) that group E1 maintained the same mean bicycle resting heart rate after detraining whereas group E2 decreased the bicycle rest-

ing heart rate by 13.4 per cent during the same time period. This result does not indicate a specificity of training.

As can be seen from Table III there appears to be no difference between the experimental groups on the mean treadmill resting heart rate after training and at retention and there are small decreases of the mean score after training and a slight increase on the retention test. An analysis of variance was performed on the data to determine if there were significant differences between the groups and among tests. The F-values (Table XIV) indicated a significant difference among tests and between groups. The Scheffe test of the differences between the group means revealed that the E1 group had a significantly higher resting heart rate than the E2 group on the retention test. The Scheffe test also revealed that the E1 group had a retention treadmill resting heart rate significantly higher than the mean score recorded during the post-training test. The percentage decrease of the treadmill resting heart rate for the bicycle trained group was smaller than the decrease for the treadmill trained group.

TABLE XIV
ANALYSIS OF VARIANCE OF THE TREADMILL RESTING HEART
RATE FOR THE EXPERIMENTAL GROUPS

Source of Variation	SS	df	MS	F
Among Tests	1345.78	2	672.89	4.49*
Between Groups	613.41	1	613.41	4.49*
Interaction	121.04	2	60.52	.4
Error	7189.08	48	149.77	
Total	9269.31	53		

*p = .05

After detraining the percentage increase for group E1 was greater than for group E2. However, this does not indicate a specificity of training effect because the F for the interaction effect was not significant.

When all the training groups are considered an examination of the mean treadmill resting heart rates (Table III) reveals a slight difference between the group means on the pre-training and the post-training test and a slight decrease for each group after training. The analysis of variance (Table XV) used to determine if the differences among the groups and between the tests are significant, revealed a significant F for both the among group effects and the between tests effect. The Scheffe test of the differences between the means revealed that the significant differences among the groups occurred on the pre-training test as reported previously. The Scheffe test also indicated a significant decrease of the mean treadmill resting heart rate after training for the E1 group.

TABLE XV
ANALYSIS OF VARIANCE OF THE TREADMILL RESTING HEART
RATE FOR ALL THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	1004.5	1	1004.5	6.13**
Among Groups	2976.32	4	744.08	4.54**
Interaction	920.44	4	230.11	1.4
Error	11798.84	72	163.87	
Total	16700.10	81		

**p = .01

The results of the analysis of the resting heart rates of the groups in this study are in agreement with research conducted by Knehr, Dill and Neufeld (53), Schneider and Crompton (61) and Cooper (23). Schneider and Crompton reported a mean resting heart rate of eighty-two for the untrained subjects and sixty-one for the trained subjects. Brouha (19) found the resting heart rate to be reduced by ten to twenty beats per minute as a result of training.

This study found a decrease in resting heart rate that ranged from 5.9 to 14.0 beats per minute after training.

The percentage differences in resting heart rates for the experimental groups between pre-training and post-training are large but the differences are not statistically significant. However, for the athletes the differences were small. Perhaps the athletes were in excellent condition at the start of training thus, any reduction in the resting heart rate as a result of training would tend to be less.

Changes in the Walk Heart Rate and the Maximal Heart Rate

The walk heart rate was recorded in order to study the heart rate response to standard work undertaken at a submaximal workload before and after a training program. The results of the analysis of this recording are compared to the results of the analysis of the maximal heart rate taken at a maximal workload.

The walk heart rates for the experimental groups (Table VI) show a decrease after training and then a slight increase during the retention test but at each test the groups are almost similar. An analysis of variance (Table XVI) of the scores was carried out to determine if the differences among the tests and between the two groups

at each testing session were significant. This analysis of variance revealed a significant F for the among test effects and no significant F for the between group effect. The Scheffe test indicated that a significant decrease in the walk heart rate after training occurred for both the E1 and E2 groups. The decrease for the E1 group was from a pre-training level of 147.4 to a post training level of 132.7 beats per minute and for the E2 group for the same period of time the decrease was from 153.8 to 126.4 beats per minute.

TABLE XVI

ANALYSIS OF VARIANCE OF THE WALK HEART RATE FOR
THE EXPERIMENTAL GROUPS

Source of Variation	SS	df	MS	F
Among Tests	4286.70	2	2143.35	7.66*
Between Groups	37.5	1	37.5	.13
Interaction	434.78	2	217.39	.78
Error	13436.22	48	279.92	
Total	18195.20	53		

*p = .05

Table VI also shows a decrease in the mean walk heart rates for all groups after training and there is also a difference between the mean scores for the groups at both the pre-training and post-training tests. The analysis of variance (Table XVII), employed to determine if the decrease in the walk heart rate was significant and if the differences among the groups were significant, revealed significant F's for the between tests effect and the among groups effects. The Scheffe test

indicated that the significant differences among the groups occurred only for the pre-training scores as reported previously. The significant decrease between the pre-training and the post-training mean walk heart rate occurred for the E1, E2 and A2 groups. The decrease for each of these groups was 14.7, 27.4 and 13.4 beats per minute respectively.

TABLE XVII

ANALYSIS OF VARIANCE OF THE WALK HEART RATES FOR
ALL THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	4216.39	1	4216.39	20.59**
Among Groups	4755.05	4	1188.76	5.81**
Interaction	1250.68	4	312.67	1.53
Error	14740.67	72	204.73	
Total	24962.79	81		

**p = .01

As can be seen in Table VI there are only slight differences among the mean maximal heart rates on all three tests for the experimental groups, and there are also slight changes after training and de-training for the same groups. An analysis of variance was used to determine if the changes over time were significant and if the groups differed significantly at each testing period. The analysis (Table XVIII) did not yield any significant difference among tests and between groups.

TABLE XVIII
ANALYSIS OF VARIANCE OF THE MAXIMAL HEART RATES FOR
THE EXPERIMENTAL GROUPS

Source of Variation	SS	df	MS	F
Among Tests	117.14	2	58.57	.45
Between Groups	146.69	1	146.69	1.12
Interaction	69.37	2	34.68	.26
Error	6304.64	48	131.34	
Total	6637.64	53		

When the mean maximal heart rates for all the training groups are examined (Table VI) it can be seen that there is a slight difference among the groups with the mean for the swim team deviation to the greatest extent. There are also slight changes in the mean maximal heart rate after training. The analysis of variance was used to determine if the differences among the groups at the post-training level and between the tests were significant. The analysis (Table XIX) revealed a significant F for the among groups effect but not for the between tests effect. The Scheffe test of the differences of the group means revealed that the significant difference among the groups occurred during the pre-training test as reported previously.

TABLE XIX
ANALYSIS OF VARIANCE OF THE MAXIMAL HEART RATES FOR
ALL THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	321.2	1	312.2	2.31
Among Groups	1854.32	4	463.58	3.4**
Interaction	402.32	4	100.58	.7
Error	9751.56	72	135.44	
Total	12320.40	81		

**p = .01

The reduction in the walk heart rates (submaximal heart rates) for the training groups is in agreement with the results of a study by Knehr, Dill and Neufeld (53). They found that the increased efficiency of grade walking on a treadmill was accompanied by a decreased heart rate of about four per cent. This study found that the percentage decrease between the means ranged from 2.5 per cent to 17.5 per cent.

The obtained maximal heart rates were similar to those reported by Bock et al.(15), Cogswell et al.(22), Hermansen and Anderson

(42) and Wang et al.(73). There were no significant changes in the maximal heart rates of the training groups over time in this study. This finding is also in agreement with the results obtained in other studies by Brouha (19), Schneider and Crompton (60) and Wahlund (72). These studies did not indicate if the changes that occurred as a result of training were statistically significant.

The results of this study indicate that the training stimulus for the experimental groups was intensive enough to produce small but non-significant reductions in the maximal heart rate. However, the same intensive training programs of only a few months in duration resulted in significant decreases of the heart rate recorded while working at a given submaximal workload. The same pattern was followed by the athletic teams.

Changes in the Recovery Heart Rate

The mean sum of the three thirty-second recovery heart rates for the three tests (Table IX) for the two experimental groups E1 and E2 show a slight decrease after training for both groups and then after detraining there was a mean increase for the groups E1 and a decrease for group E2. On all three tests the two groups were almost similar. An analysis of variance was utilized to determine if there were significant changes in the recovery heart rates after training and detraining and if there were significant differences among the scores for the groups on each test. The analysis of variance (Table XX) did not reveal a significant F for the among tests effect or the between groups effect.

TABLE XX

ANALYSIS OF VARIANCE OF THE SUM OF THE THREE THIRTY-
SECOND RECOVERY HEART RATES FOR THE EXPERIMENTAL GROUPS

Source of Variation	SS	df	MS	F
Among Tests	233.80	2	116.9	.06
Between Groups	15.68	1	15.68	.41
Interaction	98.07	2	49.04	.17
Error	13540.70	48	282.10	
Total	13888.25	53		

An examination of the mean sum of the three thirty-second recovery heart rates for the training groups (Table IX) indicates that the group means are not similar at the three test periods and that there are slight changes with training. The lowest score was recorded for the swim team and the highest score was attained by group E2. An analysis of variance of the sum of the three thirty-second recovery heart rates (Table XXI) was used to determine if the changes with training and the difference among the groups at the testing sessions were significant. The analysis revealed a significant F for the among groups effect but not for the between tests effect. The Scheffe test was used to test for significant differences in the mean recovery heart rate between groups. The test indicated that on both the pre-training and the post-training tests the two experimental groups E1 and E2 had significantly larger mean recovery rates than the mean recovery heart rate for the swim team.

TABLE XXI

ANALYSIS OF VARIANCE OF THE SUM OF THE THREE THIRTY-

SECOND RECOVERY HEART RATES FOR ALL THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	952.69	1	952.69	3.86
Among Groups	9578.93	4	1894.73	7.69**
Interaction	450.33	4	112.58	.4
Error	17749.13	72		
Total	28731.08	81		

**p = .01

In this study there were no significant decreases in the heart rate recovery for the athletes and the non-athletes after a period of training. This does not agree with the findings of Brouha (19), Herman- sen and Andersen (42), and Holmgren et al. (44), who found large de- creases in the sums of the three thirty-second recovery heart rates after subjects had completed strenuous training programs.

Changes in the Duration of the All-Out Treadmill Run

The duration of the all-out treadmill run (Table IX) for the two experimental groups show a large increase after training and then a slight decrease after detraining, but at each trial the two groups appear to be similar. An analysis of variance of the dura- tion of the all-out treadmill run (Table XXXII) was utilized to determine

if the slight differences between the groups on each test were significant and if the changes among tests were significant. The analysis revealed a significant F for the among tests effect but not for the between groups effect. The Scheffe test revealed that the E1 group had a significant increase in the duration run from a pre-training mean value of 152.3 seconds to a post-training mean value of 232.0 seconds.

TABLE XXII

ANALYSIS OF VARIANCE OF THE DURATION OF THE ALL-OUT

TREADMILL RUN FOR THE EXPERIMENTAL GROUPS

Source of Variation	SS	df	MS	F
Among Tests	48955.91	2	24477.96	10.07**
Between Groups	393.12	1	393.12	.16
Interaction	405.63	2	202.82	.08
Error	116654.59	48	2430.3	
Total	166409.25	53		

**p = .01

The means for the duration of the all-out treadmill run for all the training groups (Table IV) indicate an increase in the mean length of the run for all the groups after training except the judo team that exhibited a slight decrease. There were also increases in the mean length of time run for the groups between the pre-training and the post-training tests. An analysis of variance of the duration of the all-out treadmill run (Table XXIII) was used to determine

if the differences among the group scores at each test session were significant and if the changes in the duration of the times run after training were significant. The analysis indicated a significant F for the between tests effect and for the among groups effect. The Scheffe test revealed that the significant differences among groups occurred on both the pre-training and the post-training tests. On the pre-training test the judo team (A1) ran significantly longer than the two experimental groups E1 and E2. On the post-training test the swim teams ran significantly longer than groups E1 and E2. The Scheffe test also revealed that the hockey team and the swim team had significant increases in the mean length of time run after training.

TABLE XXIII

ANALYSIS OF VARIANCE OF THE DURATION OF THE ALL-OUT

TREADMILL RUN FOR ALL THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	119810.53	1	119810.53	11.19**
Among Groups	203996.65	4	50999.16	4.76**
Interaction	64686.16	4	16171.54	1.51
Error	770636.88	72	10703.29	
Total	1159130.22	81		

**p = .01

The results are in agreement with findings of Howell et al. (40) who reported an increase in the mean performance times for hockey

players, on the Balke-Ware treadmill test, from an initial level of 15.07 minutes before season to 21.2 minutes during the season. In the same study by Howell et al., the swimming group increased its performance time from an initial level of 18.15 minutes to 20.5 minutes and to 21.01 minutes on tests three and five respectively.

Cooper (23) found mean gains of 2.7, 1.6 and .9 minutes on the Balke-Ware treadmill test for groups of active males that participated in a 5BX program (running on the spot) respectively. Each group trained five times a week for five weeks.

Taylor (69) found low correlation ranging from $-.14$ to $-.09$ between the five minute recovery heart rate and the length of time run. Similar results have been reported by Sedgwick (62) and Durnin et al. (31). Sedgwick (62) found a correlation of $-.31$ between the recovery heart rate and the length of time run. The correlation between the recovery heart rates and the fitness index ranged from $.11$ to $-.96$.

IV. THE EFFECTS OF TRAINING ON THE SJÖSTRAND PHYSICAL

WORK CAPACITY PWC_{170} TEST

One criterion variable employed to determine the changes in work capacity as a result of training was the Sjöstrand PWC_{170} test. The PWC_{170} test is a submaximal test which employs step-wise increases in work and the heart rate response to such increases in order to determine an individuals' work capacity at a heart rate of 170 beats per minute.

The means, standard deviations and the percentage differences between the pre-training and post-training tests and between

the post-training and the retention tests are recorded in Table XXIV.

TABLE XXIV
MEANS, STANDARD DEVIATIONS AND PERCENTAGE DIFFERENCES OF
THE PWC_{170} FOR THE TRAINING GROUPS

Group	Period	Mean	S.D.	% Diff.
E1	Pre	937.1	237.8	
	Post	1129.9	299.7	+20.6
	Ret.	997.8	218.0	-10.8
E2	Pre	908.6	161.1	
	Post	1086.6	148.9	+19.6
	Ret.	1012.4	114.9	- 6.8
A1	Pre	1137.7	343.0	
	Post	1136.9	260.7	- 0.0
A2	Pre	1175.9	81.7	
	Post	1301.8	87.0	+10.7
A3	Pre	1326.8	241.6	
	Post	1265.3	203.0	- 4.6

An examination of the PWC_{170} scores for the experimental groups (Table XXIV) reveals an increase for both groups after training and then a slight decrease in the scores on the retention test. However, at each testing session the two groups appear to have similar scores. An analysis of variance of the PWC_{170} scores for the experimental groups was used to determine if two groups were similar at each testing period and if the changes over time were significant. The analysis indicated a significant F (Table XXV) for the among tests effect but not for the between groups effect. The Scheffe test reveal-

ed a significant increase in the PWC_{170} score for the bicycle trained group from an initial level of 937.1 KPM/min. to an after training level of 1129.9 KPM/min. It was concluded that the two experimental groups had similar PWC_{170} scores prior to training, after training and after detraining.

TABLE XXV

ANALYSIS OF VARIANCE OF THE PWC_{170} SCORES FOR THE
EXPERIMENTAL GROUPS

Source of Variation	SS	df	MS	F
Among Tests	294675.99	2	147337.99	3.46*
Between Groups	6913.58	1	6913.59	.16
Interaction	10813.54	2	5406.77	.13
Error	2046113.49	48	42627.36	

*p = .05

The PWC_{170} data for the experimental groups was also subjected to analysis of covariance to determine if a significant difference existed between the two groups on the retention PWC_{170} scores when selected post-training variables acted as predictors. The analysis of covariance (Table XXVI) of the retention PWC_{170} scores for the experimental groups produced no significant differences between the two groups. Any differences in the retention PWC_{170} between the two groups was accounted for by the differences that existed between the groups on the predictor variables. The predictor variables were the following post-training variables: fitness index, PWC_{170} bicycle resting heart rate, treadmill resting heart rate, walk heart rate, maximal heart rate, the

sum of the three thirty-second recovery heart rates and the duration of the all-out treadmill run.

TABLE XXVI

ANALYSIS OF COVARIANCE OF THE RETENTION PWC₁₇₀ SCORES
FOR THE EXPERIMENTAL GROUPS

Source of Variation	df	MS	Adjusted F
Between Groups	1	999.13	.16
Within	9	6314.82	
Total	10		

When the mean PWC₁₇₀ scores for the training groups (Table XXIV) are examined it is revealed that there is a decrease in the mean score after training for the judo team and the swim team and an increase for the other groups after training. There is also a difference between the mean scores for the groups on the pre-training and post-training tests. An analysis of variance of the PWC₁₇₀ scores for all the training groups was employed among the groups on both pre-training and the post-training tests, and if there were significant changes in the mean scores after training. The analysis indicated a significant F (Table XXVII) for the between tests effect and for the among groups effect. The Scheffe test revealed a significant difference among the groups on the pre-training test only and group A3 had a mean PWC₁₇₀ score significantly higher than the mean PWC₁₇₀ scores for the E1 and E2 groups. The athletic teams (A1, A2 and A3) were not significantly different from each other. The Scheffe test also

indicated a significant increase in the mean PWC_{170} scores after training for the bicycle trained group as reported previously.

TABLE XXVII
ANALYSIS OF VARIANCE OF THE PWC_{170} SCORES FOR
ALL THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	186463.13	1	186463.13	4.18*
Among Groups	1183785.51	4	295946.38	6.64**
Interaction	211778.72	4	52944.68	1.19
Error	3209499.43	72	44567.38	

*p = .05

**p = .01

The post-training PWC_{170} scores for all the training groups were subjected to an analysis of covariance to determine if there was a significant difference between the groups on the post-training PWC_{170} scores when selected pre-training variables acted as predictors.

The analysis of covariance of the post-training PWC_{170} scores for all the training groups (Table XXVIII) did not produce any significant differences between the groups. In the analysis of covariance any differences that might have occurred between the groups on the post-training PWC_{170} scores was accounted for by the predictor variables.

TABLE XXVIII

ANALYSIS OF COVARIANCE OF THE POST-TRAINING PWC₁₇₀

SCORES FOR ALL THE TRAINING GROUPS

Source of Variation	df	MS	Adjusted F
Between Groups	1	2457.0	.07
Error	33	33796.66	
Total	34		

The predictor variables are the following pre-training variables: fitness index, bicycle resting heart rate, treadmill resting heart rate, walk heart rate, maximal heart rate, the sum of the three thirty-second recovery heart rates and the duration of the all-out run.

The PWC₁₇₀ scores were also expressed per kilogram of body weight. When these scores for all the training groups were subjected to an analysis of variance a significant F (Table XXIX) was calculated for the among groups effect and for the between tests effect. The Scheffe test revealed that the significant difference among the groups appeared on the pre-training test only. The swim team had a mean score significantly higher than the mean scores for the E1 and E2 groups. The Scheffe test also indicated that the post-training mean PWC₁₇₀ scores for the bicycle trained group (E1), the treadmill trained group (E2) and the hockey team (A2) were significantly higher than the pre-training mean PWC₁₇₀ scores.

TABLE XXIX

ANALYSIS OF VARIANCE OF THE $PWC_{170}/Kg.$ FOR ALL THE
TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	39.68	1	39.68	7.12**
Among Groups	173.56	4	43.39	7.84**
Interaction	41.22	4	10.31	1.86
Error	398.61	72	5.54	
Total	653.07	81		

**p = .01

When the subjects formed two groups, the non-athletes (E1 and E2) and the athletes (A1, A2 and A3) an analysis of variance on the post-training PWC_{170} scores was performed to determine if there was a significant difference between the two groups. The F (Table XXX) was significant for the between groups effect. However, when an analysis of covariance was applied to the same post-training PWC_{170} scores for the two groups and the previously stated pre-training variables acted as predictors, the F (Table XXXI) indicated no significant differences between the two groups (athletes and non-athletes) on the post-training PWC_{170} scores. Any difference that existed between the groups on the post-training PWC_{170} scores was accounted for by the differences between the groups on the pre-training predictor variables. The predictor variables were the same as those used in the analysis of covariance of the post-training PWC_{170} scores for all the training groups.

TABLE XXX

ANALYSIS OF VARIANCE OF THE POST-TRAINING PWC₁₇₀ SCORES FOR
THE ATHLETIC AND NON-ATHLETIC GROUPS

Source of Variation	SS	df	MS	F
Between Groups	206664.0	1	207664.0	4.89*
Within	1656176.0	39	42466.05	
Total	1863840.0	40		

*p = .05

TABLE XXXI

ANALYSIS OF COVARIANCE OF THE POST-TRAINING PWC₁₇₀ SCORES FOR
THE ATHLETIC AND NON-ATHLETIC GROUPS

Source of Variation	SS	df	MS	Adjusted F
Between Groups	2457.00	1	2457.00	.07
Within	1115289.78	33	33796.66	
Total	1117746.78	34		

V. THE EFFECTS OF TRAINING ON THE JOHNSON, BROUHA AND DARLING FITNESS INDEX

The fitness index was second criterion variable used to determine the changes in work capacity after a training program. The fitness index is a maximal exhaustion run on a treadmill at 7.0 miles per hour on an 8.6 per cent grade.

The means, standard deviations and the percentage differences between the pre-training and the post-training test and between the post-training and the retention test for the Johnson, Brouha and Darling fitness index are reported for all the training groups in Table XXXII.

TABLE XXXII

MEANS, STANDARD DEVIATIONS AND PERCENTAGE DIFFERENCES IN THE
FITNESS INDEX FOR ALL THE TRAINING GROUPS

Group	Period	Mean	S.D.	% Difference
E1	Pre	40.3	10.9	
	Post	63.2	25.3	+56.8
	Ret.	50.4	16.6	-20.3
E2	Pre	39.5	6.1	
	Post	58.4	11.9	+47.9
	Ret.	50.5	11.6	-13.5
A1	Pre	71.7	25.7	
	Post	60.8	18.1	-17.9
A2	Pre	63.4	18.5	
	Post	95.1	24.6	+50.0
A3	Pre	70.1	34.7	
	Post	111.9	53.3	+59.6

An examination of Table XXXII indicates a difference between all the groups on the pre-training fitness index. These scores were subjected to an analysis of variance to determine if the groups had similar pre-training fitness index scores. The calculated F (Table XXXIII) indicated a significant difference among the groups. The Scheffe test revealed that the judo, hockey and swim teams each had a mean fitness index significantly higher than the mean fitness index

for the two experimental groups E1 and E2. There was no significant difference in the mean fitness index scores for the two experimental groups. There was no significant difference among the mean fitness index scores for the athletic team. However the mean fitness index scores for the athlete as one group was significantly higher than for the non-athletes.

TABLE XXXIII

ANALYSIS OF VARIANCE OF THE FITNESS INDICIES FOR ALL THE
TRAINING GROUPS PRIOR TO TRAINING

Source of Variation	SS	df	MS	F
Among Groups	8160.06	4	2040.02	4.52**
Within	16245.56	36	451.27	
Total	24405.62	40		

**p = .01

From Table XXXII it can be seen that the experimental groups have almost similar mean fitness indices on each test and that after training and detraining there were respective increases and decreases for the two groups E1 and E2. In order to determine if the group scores were similar at each test and if the changes over time were significant an analysis of variance was applied to the fitness index scores for the two experimental groups. The analysis revealed a significant F (Table XXXIV) for the among tests effect but not for the between groups effect. The Scheffe test indicated that both the bicycle trained group and the treadmill trained group had significant increases in mean fitness index between the pre-training and

post-training tests. The percentage gains for the E1 and E2 groups after training were 56.8 and 47.9 per cent respectively. However, this difference in increase was not significant as shown by the non-significant value of F obtained for the interaction effect.

TABLE XXXIV

ANALYSIS OF VARIANCE OF THE FITNESS INDICES FOR THE
EXPERIMENTAL GROUPS

Source of Variation	SS	df	MS	F
Among Tests	4075.21	2	2037.61	8.93**
Between Groups	21.62	1	21.62	.09
Interaction	64.76	2	32.38	.14
Error	10952.29	48	228.2	
Total	15113.88	53		

**p = .01

The mean fitness index scores for all the training groups, as shown in Table XXXII, show a large increase with training except for the judo team which had a decrease in mean scores. From the same table it can also be seen that the post-training mean fitness indices for the groups are not similar. An analysis of variance was used to determine if the increases in the fitness index over time and the differences among the groups on the post-training test were significant. The analysis indicated a significant F for the between tests effect but not for the interaction effect (Table XXV). The Scheffe test revealed that the significant differences among the groups

occurred on the post-training test. The swim team had a mean fitness index which was significantly higher than the mean fitness indices for the E1 group, the E2 group and the judo team. The hockey team had a post-training mean fitness index significantly higher than the fitness index for the E2 group. The significant increases in the fitness index after training occurred for the bicycle trained group, the hockey team and the swim team who had percentage gains of 56.8, 50.0, and 59.6 per cent respectively.

TABLE XXXV

ANALYSIS OF VARIANCE OF THE FITNESS INDICES FOR ALL
THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	11813.52	1	11813.52	16.6**
Among Groups	23047.46	4	5761.87	8.1**
Interaction	4843.99	4	1211.0	1.7
Error	51364.96	72	713.4	
Total	91079.93	81		

**p = .01

The fitness index was also expressed per kilogram of body weight. An analysis of variance of the fitness index per kilogram of body weight was employed to determine if there were any significant changes over time and if there were any significant differences in the scores among the groups. The analysis revealed a significant F (Table XXXVI) for the among groups effect and for the between tests effect

but not for the interaction effect. A Scheffe test of the group means indicated that the significant differences among the groups occurred on both the pre-training and the post-training tests. On the pre-training test the mean fitness index/Kg. for the judo team and the swim team were significantly higher than the mean fitness indices/Kg. for the two experimental groups. On the post-training test the mean fitness index/Kg. for the swim team was significantly higher than the mean fitness index/Kg. for each of the E1, E2 and A1 groups. The differences between tests occurred for the same groups that had significant increases after training when the fitness index was not expressed per kilogram of body weight. These groups were the bicycle trained group, the hockey team and the swim team.

TABLE XXXVI

ANALYSIS OF VARIANCE OF THE FITNESS INDICES/Kg. FOR

ALL THE TRAINING GROUPS

Source of Variation	SS	df	MS	F
Between Tests	227.69	1	227.69	15.67**
Among Groups	389.07	4	97.27	6.69**
Interaction	92.14	4	23.04	1.59
Error	1046.32	72	14.53	
Total	1755.22	81		

**p = .01

VI. COMPARISON AND DISCUSSION OF THE PWC_{170} AND THE FITNESS INDEX CHANGE WITH TRAINING

The increases in PWC_{170} as a result of training are in agreement with the findings of Astrand (3) and Holmgren et al. (44) who reported gradual increases in the PWC_{170} after continuous short-term training with varied workloads.

The results of the PWC_{170} tests tended to indicate some specificity of training among the athletes (Figure 5). However, when the PWC_{170} results were subjected to an analysis of variance, differences between athletic groups were non-significant. The judo team showed no increase in PWC_{170} after training as compared to the hockey team. The results of the judo team were expected since they did not partake in an intensive training program to promote changes in cardiovascular efficiency. The hockey team underwent an intensive season of training and showed a 10.7 per cent increase in the mean PWC_{170} after training. The swim team showed unexpected results on the PWC_{170} test with a 4.6 per cent decrease after training. Perhaps the type of training program undertaken by the swimmers did not lead to an improvement in the work capacity at a submaximal level, as compared to the significantly large increase in the fitness index which was an exhaustion test.

The PWC_{170} scores for the two experimental groups followed the same pattern (Figure 1) after training and detraining thus, showing no specificity of training effect on the PWC_{170} test. The increase in PWC_{170} for the two experimental groups followed the same pattern as that of the hockey team (Figure 5). After a detraining period the

percentage decrease for the bicycle trained group (10.8) was greater than that of the treadmill trained group (6.8).

Since there was an increase in the PWC_{170} scores for the two experimental groups the training stimulus was intensive enough to increase the work capacity of the two groups. This increase of the PWC_{170} score after a submaximal training program agreed with the reports of Karvonen (49) and DeVries (30).

When the PWC_{170} was expressed per kilogram of body weight (Figure 3 and Figure 7) the mean $PWC_{170}/Kg.$ scores for the groups followed a pattern similar to the pattern of the mean PWC_{170} scores when not expressed per kilogram of body weight (Figure 1 and Figure 5). This shows that weight has little effect on the results of the Sjöstrand PWC_{170} test for the subjects involved in this study. These results agree with a report by Adams (1) in 1961 but they do not agree with a report by Cotton and Dill (24) and another study reported by Adams (2) who found that weight had an important effect on the PWC_{170} score.

The increase of the fitness index after training for the bicycle trained group, the treadmill trained group, the hockey team and the swim team agree with the findings of Brouha (17, 19) and Johnson, Brouha and Darling (47). The judo team showed a drop of the mean fitness index after training (Figure 6) however, this does not show a specificity of training since the judo team did not engage in a program to affect the cardiovascular efficiency. The result only shows an absence of cardiovascular training, not a specificity of training.

There appears to be a specificity of training for the swim

team because of the high fitness index on the post-training test which was a 59.6 per cent increase from the start of training. Thus, the type of training that the swim team undertook appeared to improve the ability to do maximal work but not submaximal work as performed on the PWC_{170} test.

The fitness indices for the two experimental groups followed the same pattern after training and after detraining. (Figure 2). The changes of the fitness with training for the experimental groups followed the same pattern as the fitness indices of the hockey and swim teams with training (Figure 6). However, the fitness index for each of the experimental groups at the end of training was lower than the scores for the hockey and swim teams. The bicycle trained group had a post-training fitness index only slightly higher than the fitness index for the judo team after training.

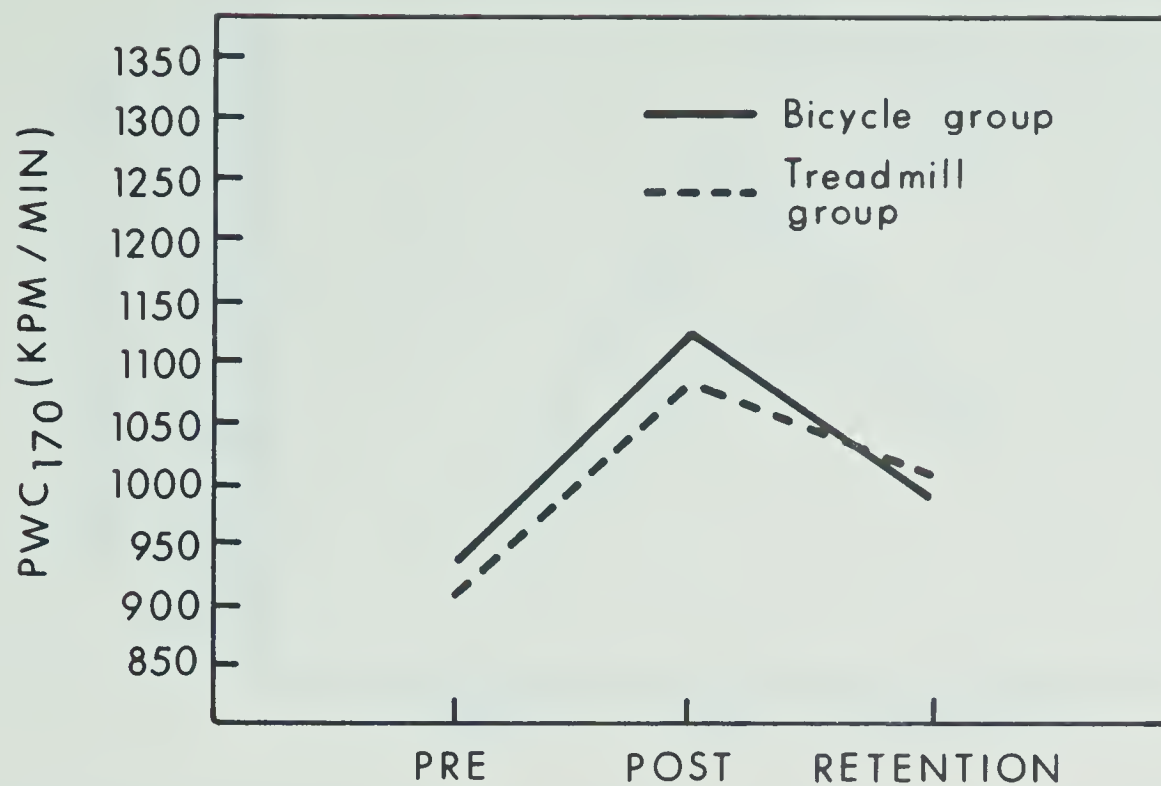
The training effect of an increase of the fitness index reported in this study is supported by research conducted by Sedgwick (62) and Brouha (19).

After a detraining period the percentage decrease of the fitness index for the bicycle trained group was 20.3 per cent and was higher than the percentage decrease for the treadmill trained group which was 13.5 per cent. The two groups were similar in scores on the pre-training test and the retention test. However, on the post-training test the bicycle trained group had a higher fitness index than the treadmill trained group. The difference between the two groups on the post-training test was not significant. This accounts for the greater percentage decrease for the bicycle trained group over the treadmill trained group after detraining. On the

retention test the difference between the group means was less than the difference between the group means on the pre-training test (Figure 2).

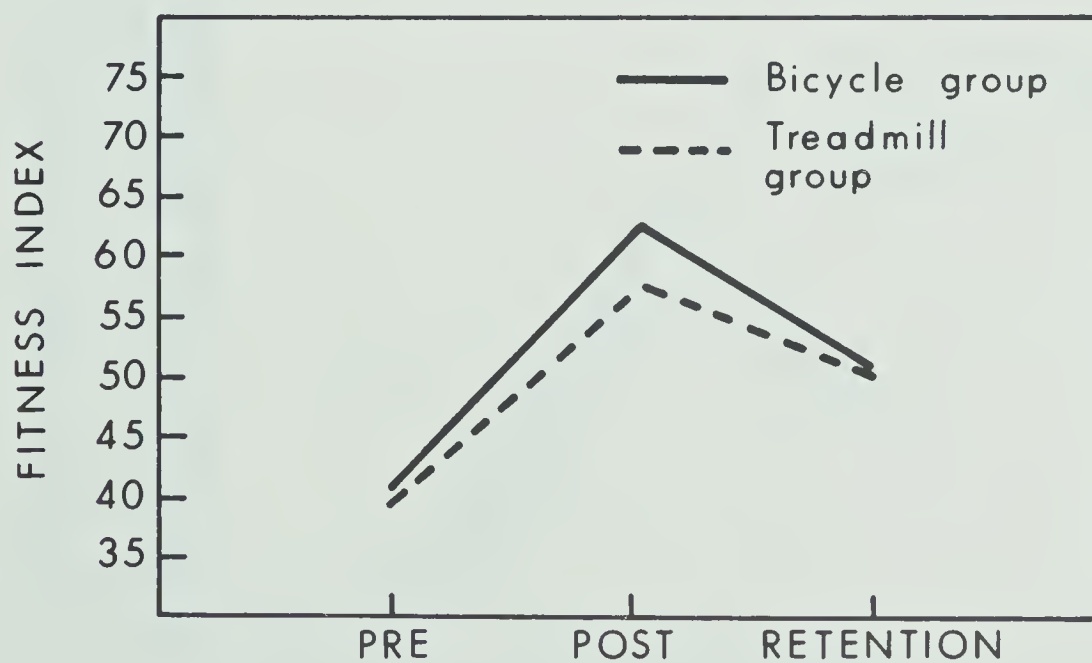
The results of the detraining study agree with Brouha (19) who stated that when training of a moderate level was interrupted for as long as a week only minor deterioration could occur on a standard exercise test. Holmgren et al. (44), Michael and Gallon (56) and Mayer (55) found similar results.

When the fitness index was expressed per kilogram of body weight (Figure 4 and Figure 8) the mean fitness indices/Kg. for the groups followed a pattern similar to the pattern of the mean fitness index when not expressed per kilogram of body weight (Figure 2 and Figure 6). This shows that weight has little effect on the fitness index for the subjects in this study. This finding does not agree with a study by Sedgwick (62) who found that weight had an effect on the fitness index.



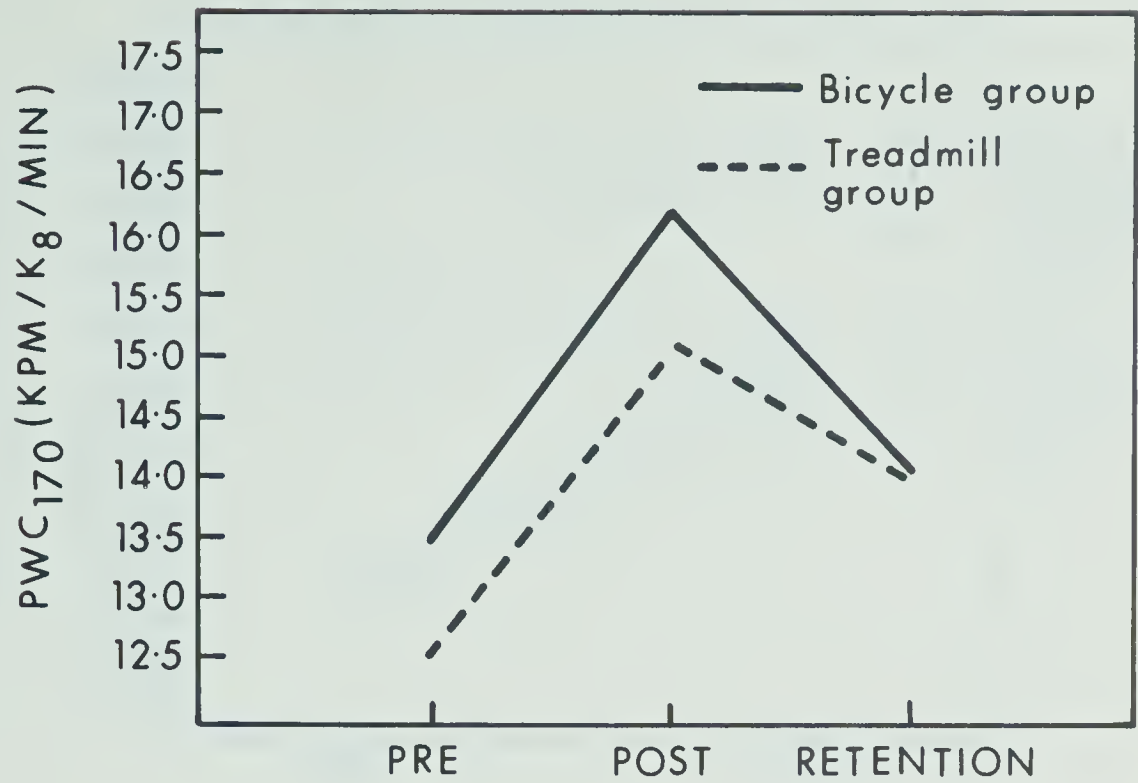
MEAN PWC₁₇₀ SCORE FOR THE BICYCLE AND TREADMILL TRAINING GROUPS ON THE SJÖSTRAND PWC₁₇₀ BICYCLE TEST.

FIGURE 1



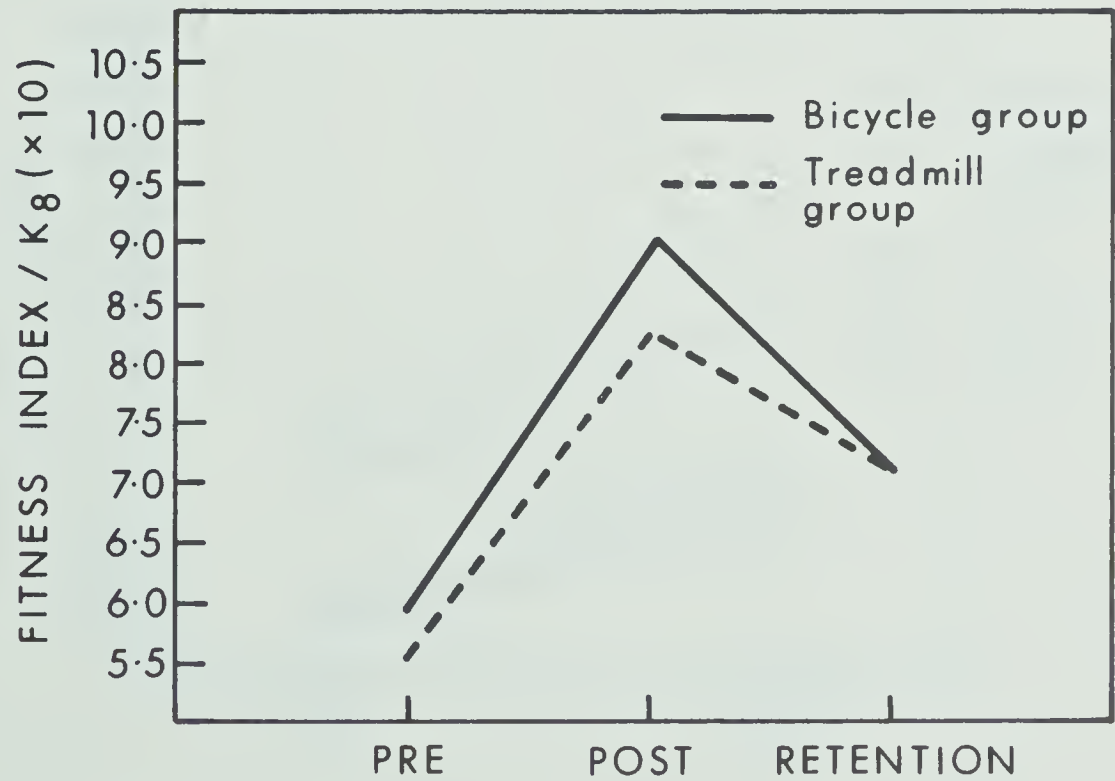
MEAN FITNESS INDEX FOR THE BICYCLE AND TREADMILL TRAINING GROUPS ON THE JOHNSON, BROUHA AND DARLING TREADMILL TEST.

FIGURE 2



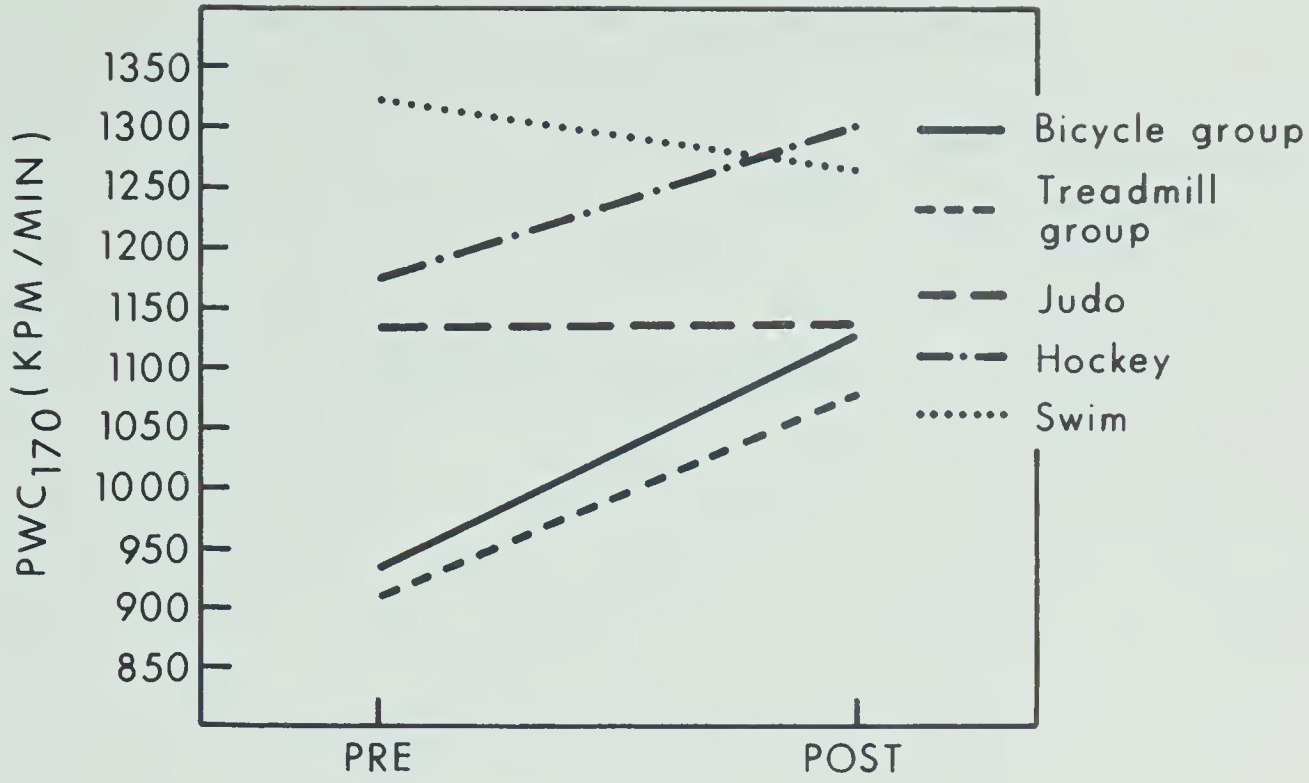
MEAN PWC₁₇₀ SCORE PER KILOGRAM OF BODY WEIGHT FOR THE BICYCLE AND TREADMILL TRAINING GROUPS ON THE SJÖSTRAND PWC₁₇₀ BICYCLE TEST.

FIGURE 3



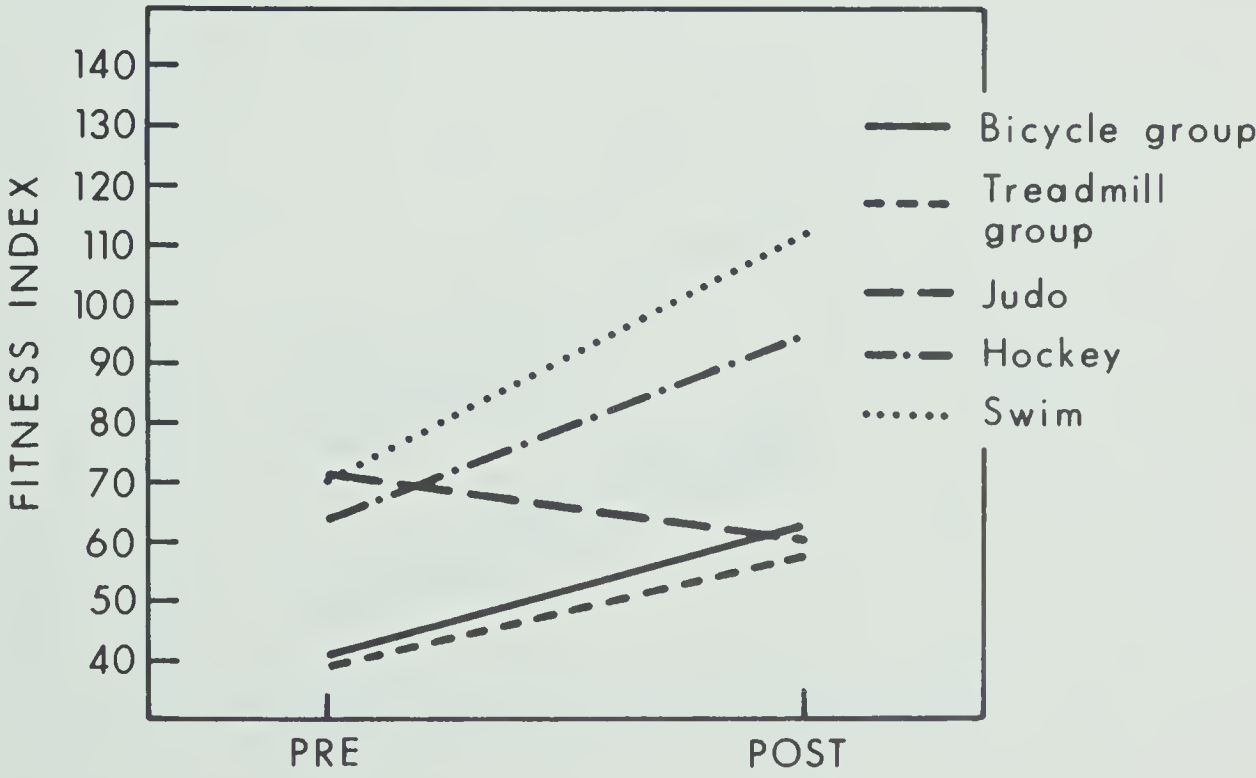
MEAN FITNESS INDEX PER KILOGRAM OF BODY WEIGHT FOR THE BICYCLE AND TREADMILL TRAINING GROUPS ON THE JOHNSON, BROUHA AND DARLING TREADMILL TEST.

FIGURE 4



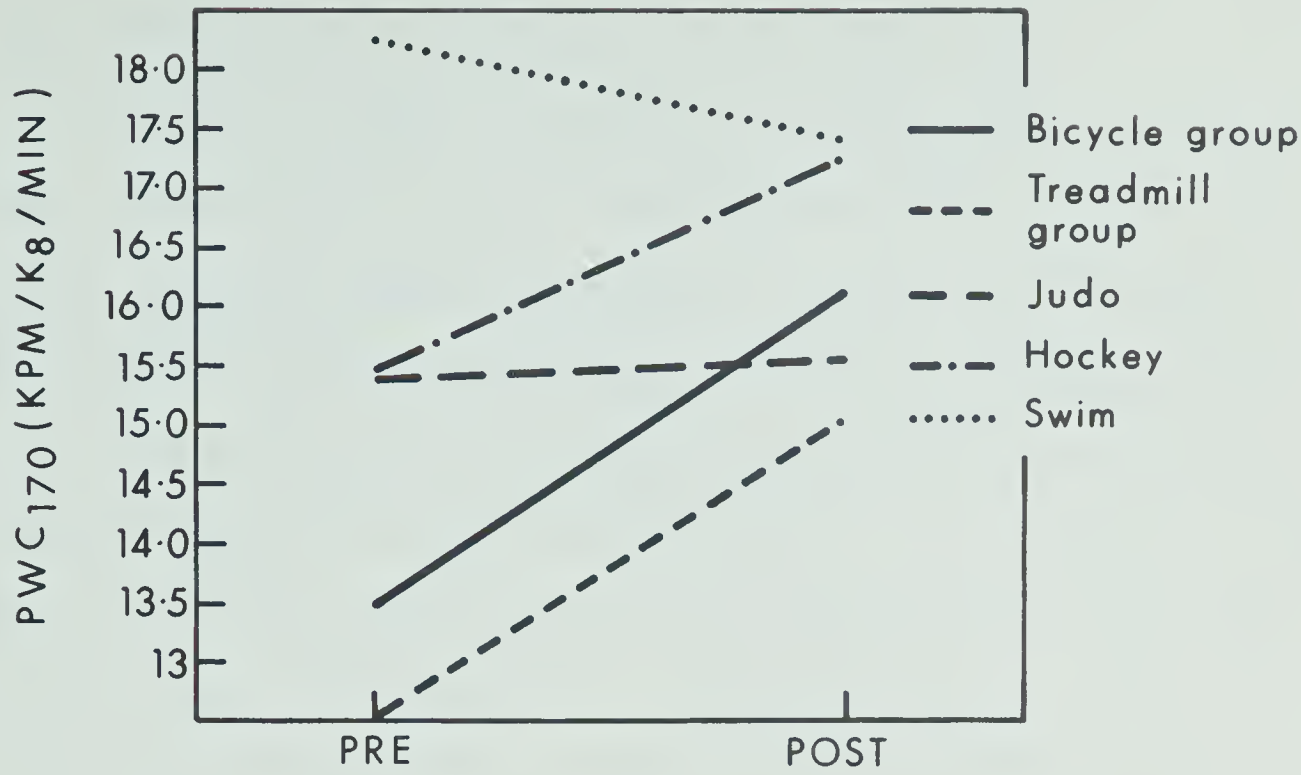
MEAN PWC₁₇₀ SCORES FOR THE EXPERIMENTAL GROUPS AND THE ATHLETIC TEAMS ON THE SJÖSTRAND PWC₁₇₀ BICYCLE TEST.

FIGURE 5



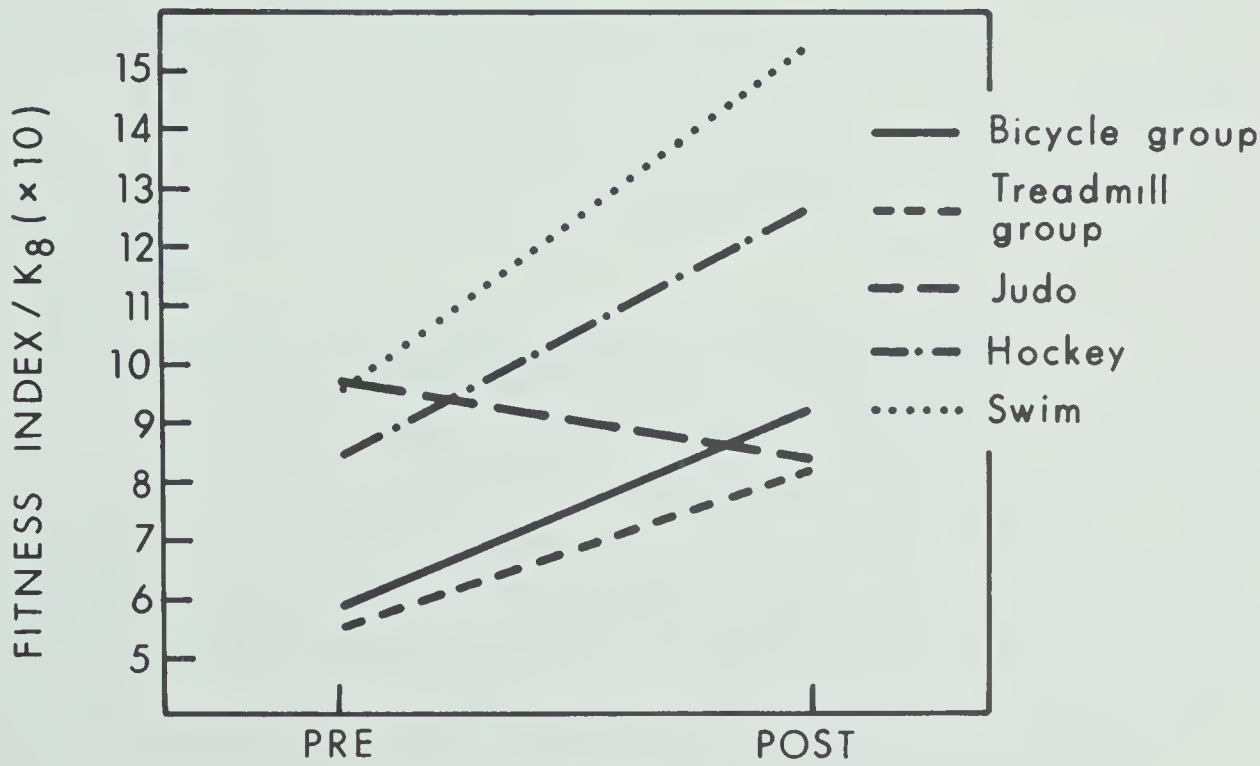
MEAN FITNESS INDEX FOR THE EXPERIMENTAL GROUPS AND THE ATHLETIC TEAMS ON THE JOHNSON, BROUHA AND DARLING TREADMILL TEST.

FIGURE 6



MEAN PWC₁₇₀ SCORE PER KILOGRAM OF BODY WEIGHT FOR THE EXPERIMENTAL GROUPS AND THE ATHLETIC TEAMS ON THE SJOSTRAND PWC₁₇₀ BICYCLE TEST.

FIGURE 7



MEAN FITNESS INDEX PER KILOGRAM OF BODY WEIGHT FOR THE EXPERIMENTAL GROUPS AND THE ATHLETIC TEAMS ON THE JOHNSON, BROUHA AND DARLING TREADMILL TEST

FIGURE 8

VII. CORRELATION OF THE PWC₁₇₀ AND THE FITNESS INDEX

When the graphs for the PWC₁₇₀, the PWC₁₇₀/Kg., the fitness index and the fitness index/Kg. were studied (Figures 1 to 8) there was no difference between the patterns followed in all the groups except the swim team that exhibited a decreased mean PWC₁₇₀ on the post-training PWC₁₇₀ test and a significant mean fitness index increase on the post-training fitness index test. A correlation of the pre-training PWC₁₇₀ scores and the pre-training fitness indices for all the training subjects yielded a correlation of +.50. When the post-training PWC₁₇₀ scores and the post-training fitness indices for all the training subjects were correlated a correlation of +.55 was obtained. The correlation between the PWC₁₇₀ scores and the fitness indices dropped to +.53 when both the pre-training and post-training PWC₁₇₀ scores and the pre-training and post-training fitness indices for all the training subjects were correlated.

These correlations between the Sjöstrand PWC₁₇₀ test and the Johnson, Brouha and Darling fitness index are significant at the .01 level.

Reliability Scores for the PWC₁₇₀ and the Fitness Index

Table XXXVII shows the Pearson Product-Moment Correlation Coefficient for the test-retest performance on the PWC₁₇₀ test and the Johnson, Brouha and Darling fitness index test. The means and standard deviations for each test are reported. Part B of the table shows the reliability of the tests when the results are expressed per kilogram of body weight.

TABLE XXXVII

MEANS, STANDARD DEVIATIONS AND RELIABILITY COEFFICIENTS
FOR THE PWC₁₇₀ TEST AND THE FITNESS INDEX

	Test 1		Test 2		r
	Mean	S.D.	Mean	S.D.	
(A)					
PWC ₁₇₀	874.5	210.2	916.61	189.1	.89
Fitness Index	47.8	26.6	47.0	17.6	.92
(b)					
PWC ₁₇₀ /Kg.	13.1	3.9	13.6	3.5	.95
Fitness Index/Kg.	7.1	4.1	7.2	3.5	.87

Zahar (75) reported test-retest reliability coefficients of .88, .89, .87 and .94 on six tests of PWC₁₇₀. Borg (16) also found high reliability coefficients of .94 and .97 on the PWC₁₇₀ test.

Taylor (69) reported a reliability coefficient of .95 for the time run during an exhaustive fitness run on a treadmill test.

VIII. STEP-WISE REGRESSION ANALYSIS

The step-wise regression analysis was employed to find a method or predicting the post-training PWC₁₇₀ scores from selected pre-training variables. The pre-training variables were (1) the fitness index, (2) the bicycle resting heart rate, (3) the treadmill resting heart rate, (4) maximal heart rate, (5) the sum of the three thirty-second recovery heart rates, (6) the duration of the all-out treadmill run, and (7) the square of the fitness index for each sub-

ject. The post-training PWC_{170} (8) was the criterion variable.

Table XXXVIII shows the means, standard deviations and R^2 for each combination of the predictor variables used.

TABLE XXXVIII
MEANS, STANDARD DEVIATIONS AND R^2 FOR THE
COMBINATIONS OF THE PREDICTOR VARIABLES

Variables	Mean	S.D.	R^2
1	55.5	24.4	.11
2	77.2	16.8	
3	75.8	15.7	
4	179.6	14.7	
5	183.9	18.2	
6	202.7	89.5	
7	2680.4	1448.9	
8	1188.7	213.2	
1-7			.46
1-6			.40
2-6			.39
3-6			.36
2,4,5,6,			.35
2,3,4,6,			.34
2,3,4,5			.33
2,3,5,6			.30
1,7			.23

The best predictor of the post-training PWC_{170} scores was a combination of all the variables from one to seven ($R^2 = .46$). However, the best combination of variables excluding the fitness index and the square of the fitness index was variable two to variable six ($R^2 = .39$). The best predictor of the post-training PWC_{170} score using only four variables was a combination of the treadmill resting heart rate, the maximal heart rate, the sum of the three thirty-second recovery heart

rates and the duration of the run in seconds ($R^2 = .36$). The standard weights for each of the variables from three to six were $-.5$, $-.41$, $+.34$ and $+.34$ respectively. When the treadmill resting heart rate was eliminated and the bicycle resting heart rate was included there was no significant drop of the R^2 when either the sum of the three thirty-second heart rates was eliminated ($.34$) or the duration of the run in seconds was eliminated ($.33$). However, when the maximal heart rate scores were eliminated as one of the four predictors and variables 2,3,5 and 6 were used the R^2 dropped to $.30$.

Thus, it was concluded that the best combination of four pre-training variables excluding the fitness index that could predict the post-training PWC_{170} scores for these subjects included the treadmill resting heart rate, the maximal heart rate, the sum of the three thirty-second recovery heart rates and the duration of an all-out treadmill run. This combination of variables was a better predictor than the fitness index alone ($r^2 = .11$).

CHAPTER V

SUMMARY AND CONCLUSIONS

Statement of the Problem.

The purpose of this study was to determine the effects of selected training programs on the Sjöstrand PWC₁₇₀ test and the Johnson, Brouha and Darling fitness index test.

Experimental Procedures

Eighteen male freshmen and twenty-three varsity athletes from the judo, hockey and swim teams were tested before and after their training programs. The freshmen subjects were randomly assigned to two equal groups, to train on a bicycle ergometer or a treadmill ergometer at a submaximal workload for five weeks. The athletes underwent a regular season of training. The freshmen subjects were retested for a retention effect after five weeks of de-training.

Description of the Groups

1. Bicycle Trained Group. This group consisted of nine subjects who trained three days a week for five weeks on a bicycle ergometer at a submaximal workload so the heart rate at the end of exercise ranged between 150-170 beats per minute. The pedal revolutions were 50 cycles per minute.
2. Treadmill Trained Group. This group consisted of nine subjects who trained three days a week for five weeks on a motor driven treadmill at a submaximal workload

so the heart rate at the end of exercise was between 150-170 beats per minute. The speed remained at 6.0 miles per hour and the grade started at 3.6 per cent and was increased at the end of the second and fourth week if the heart rate at the end of exercise in the previous training period had dropped below 150 beats per minute.

3. Judo Team. The subjects consisted of five members of the University of Alberta varsity judo team who underwent a regular season of four months of training. They did not do any intensive training to improve cardiovascular efficiency.
4. Hockey Team. This group consisted of nine University of Alberta varsity hockey players who underwent a regular season of approximately four months of training. The program involved six days of intensive skating a week.
5. Swim Team. This group was made up of nine University of Alberta swimmers who underwent a regular season of about five weeks of training. They trained six days a week with one meet each week.
6. Reliability Group. This group was randomly divided into two equal sections. Each section consisted of nine subjects. Each subject was tested on his apparatus (bicycle ergometer or treadmill ergometer) twice to determine the test-retest reliability of both instruments.

Summary of the Analysis of the Data

1. Analysis of Variance of the Resting Heart Rate. Prior to training there was a significant among groups effect and this occurred between the two experimental groups and the hockey team and the swim team. There was no significant difference among the groups on the post-training test and there was no significant difference between the tests on the bicycle resting heart rate. The percentage changes of the bicycle resting heart rate for the bicycle trained group, the treadmill trained group, the judo team, the hockey team and the swim team after training were -13.9, -16.3, -11.0, -.8 and 0.0 per cent respectively. For the treadmill resting heart rate the bicycle trained group had a significantly higher retention score than did the treadmill group. The bicycle trained group had a significantly lower post-training treadmill resting heart rate. The percentage changes of the treadmill resting heart rate for the five groups as indicated previously were -5.9, -13.1, -10.8, -6.3 and +8.1 per cent respectively.
2. Analysis of Variance of the Walk Heart Rate. Prior to training there was a significant difference among the groups and this occurred between the swim team and the two experimental groups. There were no significant differences among all the groups on the post-training walk heart rate. There was a significant decrease of

the walk heart rate after training for the bicycle trained group, the treadmill trained group and the hockey team. There was no significant increase in the mean walk heart rate for the two experimental groups after a five week period of detraining.

3. Analysis of Variance of the Maximal Heart Rate. A significant difference between the mean maximal heart rates prior to training occurred between the swim team and the judo team and between the swim team and the treadmill trained group. After training there were no significant differences among these groups and there was no significant decrease in the maximal heart rate for each group after training.
4. Analysis of Variance of the Sum of the Three Thirty-Second Recovery Heart Rates. There was no significant decrease in the sum of the three thirty-second recovery rates with training for the groups. However, there were significant differences among the groups prior to and after training and this occurred between the swim team and the two experimental groups.
5. Analysis of Variance of the Duration of the All-Out Treadmill Run. A significant difference among the groups on the pre-training test occurred between the judo team, whose members ran the longest, and the two experimental groups. On the post-training test the swim team ran significantly longer than the judo team and the treadmill trained

group. The hockey team and the swim team ran significantly longer on the treadmill test after training than before training.

6. Analysis of Variance of the PWC_{170} . Prior to training a significant difference of the PWC_{170} scores occurred between the swim team and the two experimental groups. After training there were no significant differences among the training groups. After training only the bicycle trained group had a significant increase in the mean PWC_{170} score. When the PWC_{170} was expressed per kilogram of body weight an analysis of variance revealed the same results as when the PWC_{170} was not expressed per kilogram of body weight. When the groups were divided into athletes (A1, A2 and A3) and non-athletes (E1 and E2) a significant difference occurred between the two groups on the post-training score. However, when the same data was subjected to an analysis of covariance there was no significant difference between the athletes and the non-athletes in the post-training PWC_{170} scores.
7. Analysis of Variance of the Fitness Index. Prior to training a significant difference among the groups on the fitness index occurred. After training a significant difference among the groups on the fitness index existed and the difference occurred between the two experimental groups and the hockey and the swim teams and between the

swim team and the judo team. The bicycle trained group, the treadmill trained group, the hockey team and the swim team revealed significant increases in the mean fitness index after training. When the fitness index was expressed per kilogram of body weight the analysis of variance revealed the same results as when the fitness index scores were not expressed per kilogram of body weight.

8. Reliability Scores. The reliability score for the Sjöstrand PWC_{170} test and the Johnson, Brouha and Darling treadmill test were .89 and .92 respectively. When the scores were expressed as $PWC_{170}/Kg.$ and fitness index/ $Kg.$ the reliability scores were .95 and .87 respectively.
9. Step-Wise Regression Analysis. The best combination of four pre-training variables excluding the fitness index that were used to predict the post-training PWC_{170} scores for the subjects included the treadmill resting heart rate, the maximal heart rate, the sum of the three thirty-second recovery heart rates and the duration of the all-out treadmill run. The R^2 for this combination would be of little practical value if used for predictive purposes since sixty-four per cent of the variance is unexplained.

Conclusions:

1. The Specificity of the PWC_{170} and the Fitness Index

There was no specificity of training effect for the experimental groups on either the Sjöstrand PWC_{170} test or the Johnson, Brouha and Darling Fitness Index. There was a significant increase of the PWC_{170} score for the bicycle trained group after training. The remaining groups showed no significant changes of the PWC_{170} score after training. There was a significant increase of the Fitness Index for the bicycle trained group, the treadmill trained group, the hockey team and the swim team after training. The judo team did not exhibit any significant change in the Fitness Index after training.

2. The Effect of Training on Selected Cardiovascular Variables.

There was no significant decrease after training of either the bicycle resting heart rate or the treadmill resting heart rate for the groups except the bicycle trained group. This group showed a significant decrease of the treadmill resting heart rate. There was no significant change of the maximal heart rate after training for either the experimental or the athletic team groups. There was no significant decrease of the recovery heart rate after training for either the experimental groups or the athletic team group.

3. The Test-Retest Reliability of the PWC_{170} and the Fitness Index.

The test-retest reliability coefficients for the PWC_{170} test and the Fitness Index were .89 and .92 respectively.

4. The Effect of Detraining on the PWC_{170} , the Fitness Index and Selected Cardiovascular Variables.

There was no significant decrease of either the PWC_{170} or The Fitness Index after detraining for the two experimental groups. There was no significant increase of the resting heart rate, the walk heart rate, the maximal heart rate and the recovery heart rate after detraining for the two experimental groups.

5. The Suitability of the Fitness Index as a Predictor of the PWC_{170} .

The results showed that the Fitness Index alone accounted for eleven per cent of the variance of the PWC_{170} score. It was found however, that two of the variables that made up the Fitness Index when combined with two other variables could account for thirty-six per cent of the variance of the PWC_{170} score. Therefore it was concluded that the Fitness Index alone was not a good predictor of the work capacity at a submaximal workload. A better predictor was obtained using a combination of the treadmill resting heart rate, the maximal heart rate, the sum of the three thirty-second recovery heart rates and the duration of the all-out run. The standard weights for these variables were -.5, -.41, +.34 and +.34 respectively.

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APPENDICES

APPENDIX A

AGE, HEIGHT AND WEIGHT OF
THE SUBJECTS

AGE, HEIGHT AND WEIGHT OF THE SUBJECTS

			Weight		(Kilograms)
Subject	Age	Height	Pre	Post	Retention
Bicycle Group					
1	19.8	71	75.3	75.3	75.75
2	19.4	70	70.31	70.76	71.21
3	19.8	70	73.03	72.58	72.12
4	18.3	69	76.66	77.11	77.11
5	18.6	65	57.61	58.06	58.06
6	19.4	69	61.24	61.69	62.14
7	24.2	75	78.02	79.38	80.74
8	20.9	69	65.77	66.23	63.96
9	17.8	71	61.24	66.78	60.78
Treadmill Group					
10	18.9	70	63.5	63.5	63.96
11	18.6	74	83.92	83.46	83.01
12	18.5	70	72.12	71.21	71.67
13	18.0	73	69.85	68.49	68.95
14	18.3	69	63.05	63.05	63.5
15	19.3	70	81.65	83.01	84.82
16	19.3	69	65.77	66.23	67.13
17	19.4	70	77.11	76.66	77.11
18	18.3	71	74.84	74.39	73.94
Judo Team					
19	23.3	68	67.13	68.95	
20	19.0	69	68.95	67.59	
21	25.7	69	89.81	85.73	
22	22.2	72	66.68	65.77	
23	23.0	68	72.12	73.94	
Hockey Team					
24	21.3	67	83.92	83.92	
25	21.6	72	84.82	84.37	
26	19.6	68	66.68	69.85	
27	19.1	68	69.40	68.95	
28	19.4	67	68.49	67.13	

			Weight	(Kilograms)	
Subject	Age	Height	Pre.	Post	Retention
Hockey Team (Cont'd.)					
29	21.9	70	78.93	79.38	
30	19.1	68	83.46	81.2	
31	19.6	71	74.39	73.94	
32	24.4	67	75.3	73.03	
Swim Team					
33	20.3	71	71.21	71.21	
34	22.9	71	77.11	77.57	
35	21.3	69	67.59	67.59	
36	22.4	71	78.42	74.39	
37	18.6	76	76.2	78.93	
38	17.6	69	54.89	56.25	
39	20.5	71	77.57	75.75	
40	24.2	70	83.46	78.93	
41	20.6	70	68.49	68.49	
Bicycle Reliability					
42	24.5	71	80.74	80.74	
43	18.4	69	83.46	83.46	
44	20.6	69	66.23	66.23	
45	24.3	67	63.05	63.05	
46	19.9	68	66.23	66.23	
47	18.1	68	59.87	59.87	
48	20.4	71	78.02	78.02	
49	19.3	72	68.95	68.95	
50	20.5	65	52.16	52.16	
Treadmill Reliability					
51	19.7	69	63.96	63.96	
52	20.9	70	77.57	77.57	
53	18.1	69	64.41	64.41	
54	17.4	71	68.95	68.95	
55	21.8	67	69.85	69.85	
56	18.5	70	68.49	68.49	
57	18.9	72	66.23	66.23	
58	24.5	75	94.35	94.35	
59	17.7	70	64.41	64.41	

APPENDIX B

PWC₁₇₀, FITNESS INDEX AND RAW SCORES

FOR THE EXPERIMENTAL GROUPS

PWC₁₇₀ SCORES FOR THE

EXPERIMENTAL GROUPS

Subject	PWC ₁₇₀			PWC ₁₇₀ /Kg		
	Pre	Post	Retention	Pre	Post	Retention
Bicycle Group						
1	1211.86	1160.86	1082.73	16.09	15.42	14.29
2	1019.95	1381.54	1182.7	14.51	19.52	16.61
3	1058.82	1574.25	1246.33	14.49	21.69	17.28
4	1036.4	1155.57	1126.49	13.52	14.99	14.61
5	806.26	940.03	876.14	13.99	16.19	15.09
6	780.07	837.59	873.16	12.74	13.58	10.37
7	1163.46	1353.47	1131.47	14.91	17.05	14.01
8	922.16	1167.9	946.44	14.02	17.63	14.79
9	435.1	597.89	551.14	7.10	9.84	9.07
Treadmill Group						
10	627.87	868.47	812.61	9.89	13.68	12.7
11	1144.2	1150.07	1201.79	13.63	13.78	14.48
12	945.04	1197.1	1027.59	13.1	16.81	14.34
13	927.00	881.75	951.83	13.27	12.87	13.8
14	990.13	1070.68	1051.89	15.7	16.98	16.57
15	1032.89	1102.37	1109.17	12.65	13.28	13.08
16	915.25	1112.53	1008.18	13.92	16.8	15.02
17	686.37	1348.96	896.87	8.9	17.6	11.63
18	908.82	1047.33	1052.01	12.14	14.08	14.23

FITNESS INDEX SCORES FOR
THE EXPERIMENTAL GROUPS

Subject	Fitness Index			Fitness Index/Kg ₁₀		
	Pre	Post	Retention	Pre	Post	Retention
Bicycle Group						
1	29.27	49.8	54.75	3.89	6.61	7.23
2	50.9	92.79	81.92	7.25	13.11	11.5
3	50.76	88.24	66.56	6.95	12.16	9.23
4	33.91	43.06	40.08	4.42	5.55	5.2
5	57.01	72.23	56.54	9.9	12.44	9.74
6	27.14	39.43	34.88	4.43	6.39	5.61
7	42.04	99.23	35.53	5.39	12.5	4.4
8	41.69	52.23	46.52	6.34	7.89	7.27
9	29.93	32.15	27.66	4.89	5.29	4.55
Treadmill Group						
10	30.51	52.94	57.23	4.8	8.34	8.95
11	35.05	55.43	43.2	4.18	6.64	5.2
12	39.86	50.54	46.44	5.53	7.1	6.48
13	45.38	69.81	56.73	6.5	10.19	8.23
14	49.44	76.55	61.53	7.84	12.14	9.69
15	38.58	58.3	38.99	4.73	7.02	4.6
16	44.72	72.02	63.0	6.8	10.87	9.38
17	33.33	40.97	29.18	4.32	5.34	3.78
18	38.6	49.24	58.51	5.16	6.62	7.91

RESTING PULSE RATES FOR THE
EXPERIMENTAL GROUPS

Subject	Bike Resting Pulse			Treadmill Resting Pulse		
	Pre	Post	Retention	Pre	Post	Retention
Bicycle Group						
1	117	87	85	87	93	98
2	75	69	67	62	73	89
3	51	93	62	62	47	54
4	97	82	73	92	66	70
5	80	69	72	101	67	80
6	93	75	80	91	78	86
7	86	83	85	84	60	83
8	102	70	87	79	74	82
9	118	80	98	114	88	89
Treadmill Group						
10	90	90	77	76	78	75
11	71	88	73	81	66	66
12	105	76	60	98	61	77
13	71	83	62	62	60	72
14	77	60	58	75	69	61
15	73	86	70	70	77	71
16	71	67	80	78	61	68
17	85	67	105	79	76	89
18	88	71	66	93	70	58

WALK PULSE FOR THE EXPERIMENTAL GROUPS

Subject	Pre	Post	Retention
Bicycle Group			
1	155	143	141
2	117	122	122
3	118	113	110
4	165	129	136
5	143	122	129
6	161	150	161
7	141	118	130
8	141	130	134
9	187	167	176
Treadmill Group			
1	164	136	141
2	153	129	143
3	164	143	130
4	123	113	117
5	141	123	136
6	150	120	132
7	158	134	128
8	161	129	153
9	170	111	113

MAXIMUM PULSE AND THE TIME RUN
FOR THE EXPERIMENTAL GROUPS ON THE TREADMILL TEST

Subject	Maximal Pulse			Run Time (Seconds)		
	Pre	Post	Retention	Pre	Post	Retention
Bicycle Group						
1	170	195	191	109	203	232
2	141	191	187	147	301.3	279.5
3	170	170	164	167.5	299.6	201.4
4	180	173	176	137	143.6	147.8
5	195	187	191	240	281.7	210.2
6	191	191	195	107.5	152.8	131.7
7	184	180	173	169	360	174.5
8	180	184	180	164.3	213.3	186
9	204	195	204	129.7	132.3	120.8
Treadmill Group						
10	176	195	200	119.3	209.4	219.5
11	195	184	187	135.7	202.4	159.7
12	200	184	191	168.7	195	183.5
13	180	200	191	162	271.2	209
14	176	176	187	179.7	268.8	222.2
15	187	191	167	145.6	229.3	145.2
16	184	184	187	161.2	262.4	238.1
17	187	176	195	138	156.5	117.3
18	187	184	180	149	174.3	173.8

RECOVERY HEART RATES

Subject	Recovery 1-1½ minuts			Recovery 2-2½ minuts			Recovery 4-4½ minutes		
	Pre	Post	Retention	Pre	Post	Retention	Pre	Post	Retention
Bicycle Group									
1	67.5	75.8	79.7	62	65.5	69.2	56.7	62.5	65.7
2	51.7	62	65.7	46.2	50.7	54.2	46.5	59.5	51
3	63	63.5	58.5	54.5	56	47	48	50.5	45.5
4	72.5	66	70.2	69	52.7	60.7	60.5	48.5	55
5	78.5	71	68.7	68	65	59.5	63.5	59.2	59.5
6	74	71.5	70	65	63	61.7	60	59.5	57.5
7	71	66.2	71.5	66	58.7	65.2	64	56.5	55.5
8	74	77.7	75.7	65	67.5	64.7	57.7	58.7	59.5
9	82	74.3	82.7	70.5	69.3	71	64.7	61.7	65
Treadmill Group									
10	72	72.7	74	64	65.7	61.2	59	60	57
11	73	70.5	70	62	58.7	59.2	59	53	56
12	80	73.5	75.7	68	64.2	65.2	64	55.2	57.2
13	69	72.5	71	58.5	64.2	60.2	51	57.7	53
14	70	66	69.2	58	56.2	57	52	53.5	54.2
15	77	72.7	70.5	61.5	64	61.7	52	59.7	53.7
16	68	69.2	70.5	59	58.7	61.2	53	54	57.2
17	75	72	73.5	69	61.3	66	63	58.3	61
18	75	73.5	57.7	61	56	51	57	47.2	40

WORK LOAD, RESTING HEART RATE AND EXERCISE HEART RATE

RECORDING DURING THE TRAINING PERIOD

Subject	Work Load		Resting Heart Rate		Exercise Heart Rate	
	1st Week	5th Week	1st Week	5th Week	1st Week	5th Week
Bicycle Group						
1	3.5	4.0	93	76	155	161
2	4.0	4.75	75	68	155	173
3	4.25	5.0	90	67	161	158
4	3.5	4.25	90	68	167	167
5	3.5	3.75	82	74	176	176
6	3.0	3.25	85	83	167	176
7	4.0	4.75	87	71	167	164
8	3.0	4.0	87	75	170	161
9	2.0	2.5	117	87	170	195
Treadmill Group						
10	3.6	5.6	98	69	191	184
11	3.6	5.6	83	75	176	180
12	3.6	5.6	81	58	191	184
13	3.6	5.6	70	67	180	176
14	3.6	5.6	89	59	173	173
15	3.6	5.6	82	78	176	173
16	3.6	5.6	61	77	173	167
17	3.6	5.6	98	92	184	184
18	3.6	5.6	53	69	191	180

APPENDIX C

PWC₁₇₀, FITNESS INDEX AND RAW SCORES

FOR THE ATHLETIC TEAMS

PWC₁₇₀ AND FITNESS INDEX FOR THE ATHLETES

Subject	PWC ₁₇₀		PWC ₁₇₀ /Kg		Fitness Index		Fitness Index/ Kg x 10	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Judo Team								
1	1079.78	1245.82	16.08	18.07	88.16	78.72	13.13	11.42
2	753.48	846.14	10.94	12.42	26.52	33.74	3.84	4.99
3	1694.37	1457.24	18.87	16.99	86.18	73.83	9.6	8.61
4	1041.25	889.68	15.62	13.53	82.53	52.44	12.38	7.97
5	1119.57	1245.55	15.52	16.85	74.87	65.37	10.38	8.84
Hockey Team								
6	1141.67	1274.11	13.6	15.18	57.1	59.11	6.8	7.04
7	1139.91	1162.7	13.44	13.78	91.8	84.3	10.82	9.99
8	1196.23	1237.35	17.94	17.71	88.7	135.14	13.3	19.35
9	1060.89	1321.96	14.57	19.17	49.4	87.06	7.12	12.63
10	1107.74	1319.78	16.17	19.66	77.8	116.82	11.36	17.4
11	1324.5	1427.25	16.78	17.98	57.3	117.75	7.26	14.83
12	1139.3	1216.48	13.65	14.98	40.7	68.8	4.88	8.47
13	1267.58	1398.53	17.04	18.91	61.1	87.77	8.21	11.87
14	1205.09	1357.88	16.0	18.59	46.24	99.04	6.14	13.56
Swim Team								
15	1373.3	1175.44	19.29	16.51	108.0	120.6	15.17	16.94
16	1568.8	1458.7	20.34	18.8	43.9	66.6	5.69	8.59
17	1153.7	1122.66	17.07	16.61	59.6	99.4	8.82	14.71
18	1657.9	1532.07	21.14	20.6	103.3	226.4	13.17	30.43
19	1596.9	1500.24	20.96	19.01	59.5	113.5	7.81	14.38
20	999.6	908.06	18.21	16.15	38.3	57.8	6.98	10.28
21	1334.0	1197.73	17.20	15.81	32.0	63.7	4.13	8.41
22	1065.9	1293.48	12.77	16.39	56.8	102.2	6.81	12.95
23	1191.0	1199.34	17.39	17.51	129.4	156.8	18.89	22.85

RESTING PULSE, WALK PULSE AND MAXIMAL PULSE

Bike Resting Pulse			Treadmill Resting Pulse		Walk Pulse		Maximal Pulse	
Subject	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Judo Team								
1	101	67	80	71	127	117	184	187
2	100	89	94	77	145	158	194	184
3	63	62	76	60	125	107	187	187
4	79	79	93	81	134	127	195	191
5	65	66	74	83	153	158	187	180
Hockey Team								
6	74	70	80	61	141	120	191	187
7	72	80	81	68	134	136	191	180
8	67	62	75	69	136	125	184	191
9	62	48	63	51	141	117	187	180
10	72	51	72	65	134	118	184	187
11	65	81	90	75	130	127	173	173
12	74	76	85	87	150	122'	136	180
13	61	69	74	77	141	145	187	187
14	55	51	46	47	130	106	180	172
Swim Team								
15	53	55	61	52	127	102	184	180
16	87	79	63	84	129	138	161	170
17	52	51	47	47	122	106	143	170
18	74	85	70	74	130	113	167	187
19	53	52	47	77	105	111	167	158
20	60	78	55	50	123	110	170	180
21	75	74	74	60	132	129	170	176
22	77	52	41	60	127	115	167	184
23	73	80	84	82	125	125	187	204

RUN TIME AND
RECOVERY HEART RATES

Run Time (Seconds)		Recovery 1-1½ Minutes		Recovery 2-2½ Minutes		Recovery 4-4½ Minutes		
Subject	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Judo Team								
1	365	279	83	66.5	63	57	61	54.2
2	105	115.8	77	65.7	63	55	58	51.2
3	307	157	69	57.7	60	48.5	57	43.5
4	293	237.4	63	59	54	51	53	50.5
5	277	257.8	68	73.5	60	61.8	57	61.8
Hockey Team								
6	226	207	77	65.8	63	57	58	52.3
7	338	275	71	61.7	60	53.2	53	48.2
8	338.6	493.8	75	69.2	59	57	57	56.5
9	173.5	294.6	67	67.5	56	54	52	47.7
10	274	411.2	63	67	59	55.5	54	53.5
11	210.5	434.5	67	67.5	61	60	56	57
12	132	220	58	63.8	57	52.5	47	43.5
13	231.5	321.4	72	67.7	62	61.2	56	54.2
14	172	331.2	69	62	61	55.2	56	50
Swim Team								
15	372	362.6	63.5	57	56.2	57.8	52.5	46.5
16	150.7	227.2	65	63	57	57	50	50.3
17	184	254.4	57	58.3	51.2	40	46.2	39.5
18	361.6	840.0	63.5	68.5	56.7	60	55	57
19	175.3	361.6	54	60.5	45	51	48	48
20	113.4	183.5	54	63.5	49	49.8	44.5	45.8
21	121.8	228.8	72	68.8	62	59	56.5	52
22	168.2	294.9	52.7	56	48.5	46.3	46.7	42
23	489.2	598.3	70.5	71.8	60.5	61.8	58	57.5

APPENDIX D

PWC₁₇₀ AND FITNESS INDEX FOR

THE RELIABILITY GROUPS

BICYCLE RELIABILITY GROUP PWC_{170} SCORES

Subject	PWC_{170}		$PWC_{170/Kg}$	
	Test 1	Test 11	Test 1	Test 11
1	768.62	971.23	9.52	12.03
2	778.02	946.49	9.32	11.34
3	740.53	767.46	11.18	11.59
4	1364.32	1332.69	21.64	21.14
5	1059.8	975.01	16.0	14.72
6	797.81	877.78	13.33	14.66
7	772.91	735.89	9.91	9.43
8	896.72	946.29	13.01	13.72
9	718.72	696.81	13.78	13.36

TREADMILL RELIABILITY GROUP FITNESS INDEX SCORES

Subject	Fitness Index		Fitness Index/Kg x 10	
	Test 1	Test 11	Test 1	Test 11
1	43.58	42.7	6.81	6.68
2	33.86	34.73	4.37	4.48
3	31.84	36.94	4.94	5.74
4	28.7	33.2	4.16	4.82
5	54.02	63.7	7.73	9.12
6	47.33	47.8	6.91	6.98
7	69.0	87.8	10.42	13.26
8	16.42	22.52	1.74	2.39
9	105.85	73.43	16.43	11.4

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